Forest Products Journal

Porosity of Pine Logs in Pond Storage & Treatment, p. 2

Vol. IX, No. 9 September, 1959

Wood Particles, Flakes, Shavings, Splinters and Chips can be Dried by High Temperature . . . p. 5-A

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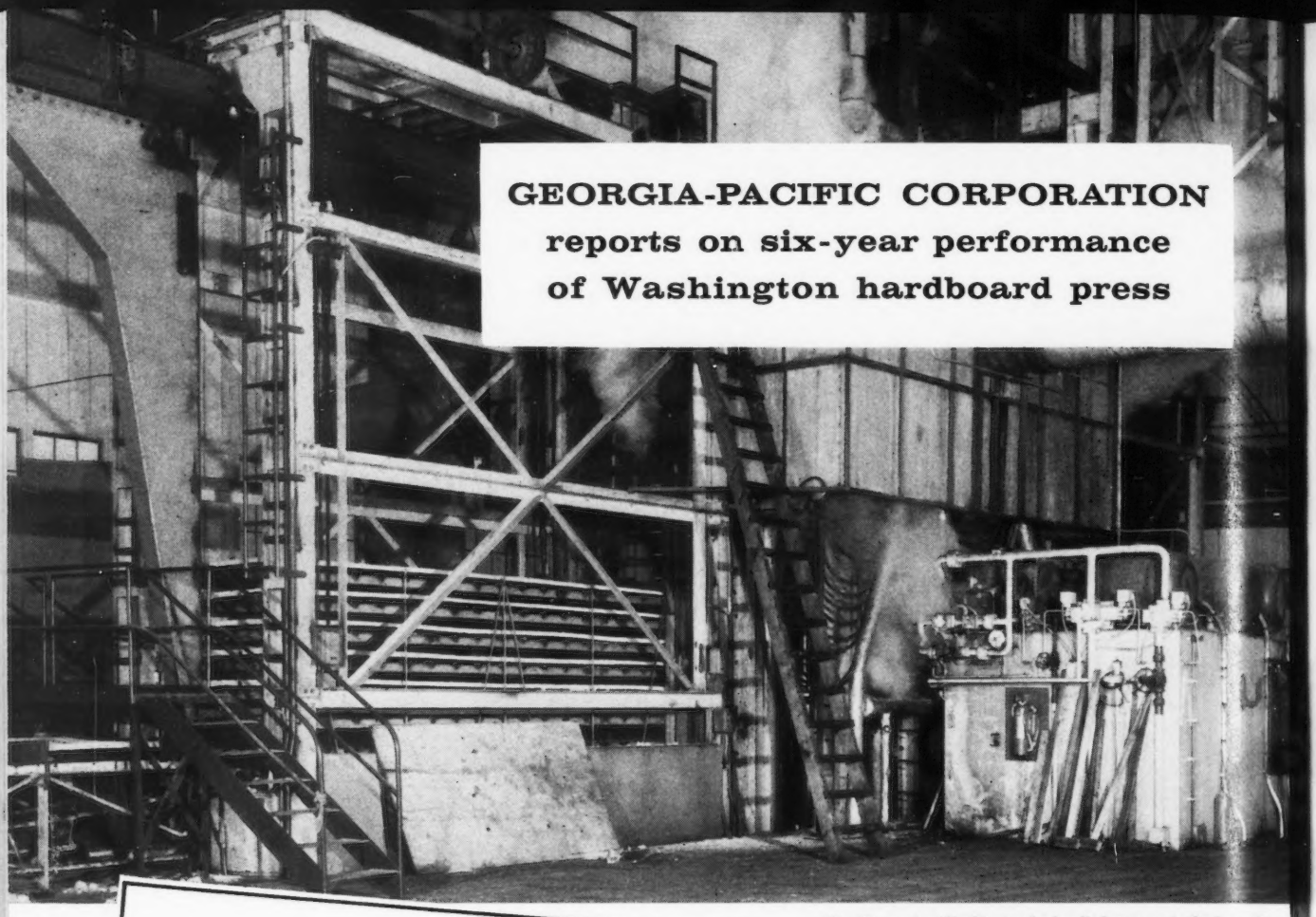

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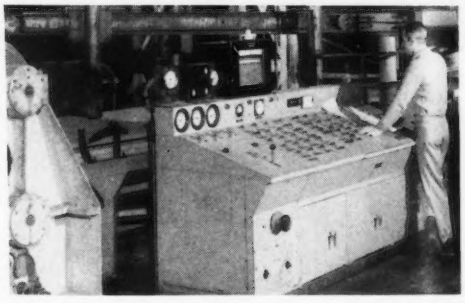

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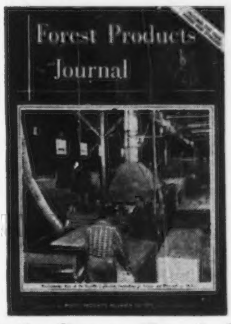

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FPRS News-Digest

Composition Board, New Machinery, Utilization Ideas to be Studied at Northeast Section Meeting, October 29, 30

The Fall Meeting of the Northeast Section will be held Oct. 29 and 30 at the Hotel Bancroft, Worcester, Mass., according to J. Allan Hauter, Section chairman. The Program is under the direction of Prof. Richard West, Rutgers University.

Session I—Use of Different Types of Wood Composition Board in Construction. Papers on Fiberboard, Particle Board, Plywood and Hardboard.

Session II—New Developments in Wood Machining and Machinery. Subjects: 1) Circular Sawing Experiments on a Radial Arm Saw. 2) Experimental Small-Scale Veneer Cutting. 3) New Developments in Logging and Milling Machinery. 4) Wood Cutting—a new Russian film presented to the College of Forestry at Syracuse by the Leningrad Forest Technology Academy.

Session III—New Developments in Wood Utilization. 1) Hydropyrolysis, a New Approach to Wood Utilization. 2) Architectural and Structural Uses of Laminated Timber. 3) Small Particle Board Plant to Utilie Mill Residues. 4) Coffee Stain and Blue Stain—panel discussion of cause and cure.

Dr. E. S. "Scotty" Harrar, Dean of School of Forestry, Duke University, and President of FPRS will address the annual banquet on Thursday evening.

Informal discussion sessions on Research and Seasoning will be led, Thursday evening, by Dr. G. Kitazawa and Prof. Harold Gatslick.

Plant tours, Friday afternoon, are being planned by Frank Parrish.

Registration and preprints, Members, $5; non-members, $7.00. Preprints only, $2 per set.

Dr. Fred E. Dickinson to Address Rocky Mountain Section Meeting in Denver, Oct. 23

FPRS Rocky Mountain section will meet Friday, Oct. 23, from 10:00 a.m. to 4:00 p.m. in the Cosmopolitan Hotel, Denver. The discussion during the morning will deal with "Fire-Retardant Applications to Wood." Dr. Fred Dickinson, Director of the California Forest Products Laboratory, Richmond, Cal., and FPRS Southwest Region Board Member will address the afternoon session on the subject, "The Wood Industry at the Crossroads."

FPRS North Central Region to Study Wood Finishing Problems in Chicago, November 5 and 6

Factory finishing of all types of wood products—lumber and plywood paneling, board products, furniture, cabinets, millwork, flooring, wooden containers and others—will be the theme of the two-day meeting which will bring together the society's Midwest, Great Lakes, Upper Mississippi Valley and Ohio Valley Sections.

The location will be the Conrad Hilton Hotel, Chicago, according to Gen'l. Chmn., J. J. Allegretti, Masonite Corp., and Donald Lubeck, Hammond Organ Co.

"BETTER FACTORY FINISHING OF WOOD PRODUCTS"

Thurs. a.m., Nov. 5—

Airless Spraying—Nordson Corp., Amherst, Ohio. Roller Coating—Gasway Corp., Chicago. Pressure Curtain Coating—Wilco Machine Works, Memphis. Automatic Spraying—Binks Mfg. Co., Chicago. New Finishing Materials—Lilly Co., High Point, N. C.

Featured speaker at the Official Luncheon, will be FPRS President, Dr. E. S. "Scotty" Harrar.

Thurs. p.m., Nov. 5—

Conveyor Systems—Conveyor Systems, Inc., Morton Grove, Ill. Flow Coating and Dipping—Spra-Con Co., Chicago. Catalyst Spraying and Controlled Low Temperature Spraying—DeVilbiss Co., Toledo. Infrared Drying—Fostoria Corp., Fostoria, Ohio. Pumping Systems and Hydrospray Process—Gray Co., Inc., Minneapolis, Minn.

Evening—Traditional "Paul Bunyan Hour" and Banquet.

Fri. a.m., Nov. 6—

Preparation for Wood Finishing—a "short course" on coated abrasives and their proper application in preparation of wood for better finishing—new types of sanding machines, equipment and tools. "Abrasive Grits, Backings and Uses," Minnesota Mining and Mfg., St. Paul. "Sanding in the Plant Layout," Carborundum Co., Niagara Falls, N.Y. "New Applications and Developments," Behr–Manning Co., Troy, N. Y.

Fri. p.m., Nov. 6—

Open Forum on Wood Finishing Problems—participation by members of the audience, and panelists.

It is recommended that persons desiring to attend make hotel reservations at the Conrad Hilton or hotel of their choice at an early date. Pre-registration for the meeting is under the direction of Roy Newstedt, the Wurlitzer Co., De Kalb, Ill. Registration fee, $5 per person.

Important FPRS Dates

October 23, 1959: Rocky Mountain Section Meeting, Denver, Colorado.
October 29–30, 1959: Northeast Section Meeting, Worcester, Massachusetts.
November 5–6, 1959: North Central Regional Meeting, Chicago, Illinois.
November 12–13, 1959: Carolina–Chesapeake Section Meeting, Hickory, N. C.
December 3–4, 1959: Southeastern Section Meeting, Daytona Beach, Florida.
June 5–9, 1960: Fourteenth National Meeting, Montreal, Canada.

Carolinas-Chesapeake Section to Explore "Wood's Competition" at Hickory, N. C., Nov. 12-13

The Carolinas-Chesapeake Section will hold its annual meeting in Hickory, North Carolina, on November 12 and 13, according to Ken Redman, Section Chairman. The theme of this year's meeting in Woods' Competition and several of the papers to be presented will relate to this topic. However, there will be other papers dealing with specific technical problems that will be of interest to all those concerned with the conversion of wood into useful products. For example, Dr. A. J. Stamm will give a paper on the subject of "Stabilization of Wood with Polyethylene Glycol.

In addition to the presentation of technical papers, there will be several plant tours through some of the surrounding furniture plants on Friday afternoon.

Sam Freeman, Chairman of the Arrangements Committee, has obtained the facilities of the Hickory Elks Club for the meeting.

Southeastern Section to Meet at Daytona Beach, Florida, Dec. 3 and 4

By popular demand the Southeastern Section is again holding its 1959 meeting at Daytona Beach, Florida, on December 3 and 4. The meeting will be held at the Daytona Plaza, a large modern hotel on the waterfront.

"DEVELOPMENTS IN THE FOREST PRODUCTS INDUSTRY"

December 3—10:00 A.M.—Noon—Registration

1:30 P.M.—PULP AND PAPER, Presiding: William L. Belvin, Director, Herty Foundation, Savannah, Georgia

1. "The Availability and Use of Some Hardwoods"—P. W. Chestnolvick, Forest Economist, International Paper Company, Mobile, Alabama.
2. "Closer Utilization—Key to Efficient Pulpwood Production"—J. A. Holekamp, Forest Engineer, American Pulpwood Association, Sylacauga, Alabama.

3. "Hardwoods for Pulping Purposes"—J. H. Ainsworth, Vice-President, Noralyn Paper Mills, Inc., Baton Rouge, Louisiana.
4. Panel Discussion: William L. Belvin, Moderator; P. W. Chestnolvick; J. A. Holekamp; J. H. Ainsworth; Ralph B. Parker, Pilot Plant Superintendent, Herty Foundation, Savannah, Georgia.

4:30 P.M.—Business Meeting; 6:00–7:00 P.M.—Social Hour; 7:00 P.M.—Banquet

December 4—9:00 A.M.—FINISHES AND PLYWOOD, Presiding: Reland B. Westgate, Plant Manager, Georgia-Pacific Corporation, Savannah, Georgia.

1. "Printing Plywood"—Mr. Joe Thiel, American Marietta Corporation, Kankakee, Illinois.
2. "Finishing Wood"—Mr. Hoyt Bray, President, Reliance Varnish Company, High Point, North Carolina.
3. "Plastic-Plywood Laminate"—Mr. Bernard Hewitt, Chairman, Industrial Plywood Company, Inc., Jamaica, New York.

1:30 P.M.—RESIDUE UTILIZATION, Presiding: Rufus H. Page, Technologist, Southeastern Forest Experiment Station, Asheville, North Carolina.

1. "Continuous Carbonization of Fine Residue"—Mr. E. E. Dargan, President, Charcoal Industries, Inc., Conway, South Carolina.
2. "Unitized Parquet Flooring"—Mr. Ralph Peter, U.S. Forest Service, Athens, Georgia.
3. "Background and Development of a Chip-Producing Saw"—Bill Briggs, Simonds Saw and Steel Company, Fitchburg, Massachusetts.
4. "Economic Implications of Chip-Producing Saws"—Parks Brewer, Chip Procurement Supervisor, Buckeye Cellulose Corporation, Foley, Florida.
5. Panel Discussion: Rufus H. Page, Moderator; Bill Briggs, Parks Brewer; Jake Griffin, Wells-Griffin Lumber Company, Valdosta, Georgia; Lawton Holland, Simonds Saw and Steel Company, McRae, Georgia.

Lumber Seasoning Courses Nov. 30 & Dec. 7

Two sessions of a six-day course in lumber seasoning will be offered on the West Coast this fall according to a joint announcement by F. E. Dickinson, Director of the California Forest Products Laboratory, and L. D. Espenas, Acting Director of Forest Products Research at the Oregon Forest Research Center. The first will be held in Corvallis, Oregon, beginning November 30, while the other will be held in Richmond, California, beginning December 7.

The two courses will be similar in organization, content and cost. Cooperating with the California laboratory are the Pacific Southwest Forest and Range Experiment Station and the School of Forestry, University of California. The Pacific Northwest Forest and Range Experiment Station and the School of Forestry, Oregon State College, are cooperating with the Oregon laboratory. The U.S. Forest Products Laboratory, Madison, Wisconsin, is cooperating with both organizations in providing course materials.

The course content is aimed primarily for the benefit of kiln operators, but personnel from management, supervisory and sales staffs should find attendance profitable as well as interesting; and they are encouraged to attend. The instruction will consist of lectures, demonstrations, laboratory exercises, and actual operation of the drying equipment at the host laboratory.

Enrollments will be limited to 30 persons. Fee of $75 a person defrays actual costs. Application forms may be obtained by writing to Department of Conferences and Special Activities, University Extension, 2441 Bancroft Way, Berkeley 4, California, or to the Oregon Forest Research Center, P. O. Box 571, Corvallis, Oregon.

John K. McDonald Named FP Journal Editor

Madison—John K. McDonald, has been appointed editor of the Forest Products Journal. A graduate of the University of Wisconsin School of Journalism, McDonald joined the staff of the U. S. Forest Products Laboratory as an editor of research publications in 1951.

In the 5½ years he worked at the Laboratory, McDonald had an opportunity to familiarize himself with many phases of wood technology—from saw milling to wood chemistry. In collaboration with others on the U.S.F.P.L. staff, he performed editorial duties on such well-known publications as the Wood Handbook and Wood-Frame House Construction, two of the more widely disseminated publications on wood technology and its practical application.

He left the Laboratory in 1958 to operate a business of his own, and he was also associated with the Mutual Life Insurance Company of New York before he joined the Journal staff.

"Being in business for yourself is fine," McDonald said, "but I welcome this opportunity to re-enter the forest products field, and I hope to serve you well."

U.S. Forest Products Lab. Releases Five New Publications

"Heating Rates for Logs, Bolts, and Flitches to be Cut into Veneer" is the title of a Report 2149 by H. O. Fleischer, chief of the Laboratory's division of timber processing. It describes a method for quickly and easily determining schedules for heating logs in water or in steam before they are to be cut into high-quality veneer.

Report No. 2152, "Effect of Ventilating and Handholes on Compressive Strength of Fiberboard Boxes," was prepared by engineers C. C. Peters and K. Q. Kellicutt. It contains data on the reductions in the strength of fiberboard boxes that had ventilating and handholes cut into them.

To aid manufacturers in producing improved pallets specifically designed for known weights of commodities, a new report, No. 2153, titled, "Load-Carrying Capacity of Deck Boards for General-Purpose Pallets," was compiled by Engineer T. B. Heebink. An added feature is a handy circular calculator, for computing deck-board thickness or load capacity of pallets, that can be assembled from the last three pages of the report.

Report No. 1275, "Strength Tests of Spliced Studs," has been revised by E. C. O. Erickson, engineer at the Laboratory, as the result of new methods of making end joints and advances in glues and gluing techniques that have been developed since publication of the original report. The Laboratory's Report No. 1983, "Hollow-Core Flush Doors," also has been revised to include the latest information on the design factors, fabrication, and performance tests of hollow-core flush doors.

Single copies of these reports are available free upon request from the Director, Forest Products Laboratory, Madison 5, Wis.

Five-Day Softwood Lumber Course at Michigan State U. December 7–11, 1959

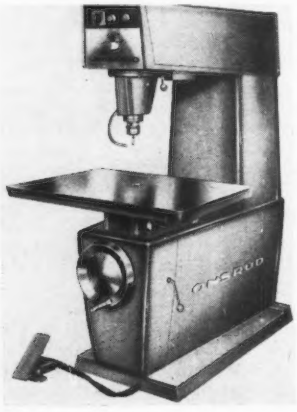
The course, to cover grading, properties, uses, will be held at the Kellogg Center, East Lansing, Mich. It is designed for wholesalers, retailers, lumber salesmen, inspectors, graders, building contractors, manufacturers and architects.

Cooperating organizations include, the Southern Pine Inspection Bureau; Western Pine Association; West Coast Lumber Inspection Bureau; and California Redwood Association.

During the first portion the staff of the Dept. of Forest Products will lecture and answer questions. During the remainder, representatives of the Association will discuss and illustrate grades, rule books, etc.

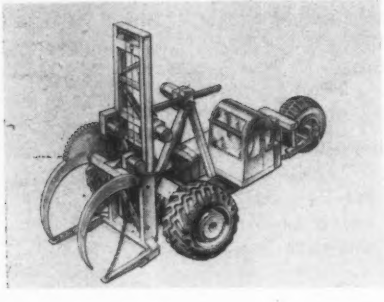
Registration fee, $40 per person. Rooms and meals extra. For formal application, write Softwood Lumber Course, Continuing Education Service, Mich. State U., E. Lansing, Mich.

NEW PRODUCTS and Literature



Heavy Duty Routers

Fast production, smooth finish, and easier set-up and operation are promised for users of the 1024 and 1036 rounters introduced this year by Onsrud Machine Works, Inc., Niles 48, Ill. A foot-valve operated pneumatic control system for vertical feed of the spindle is one of the important new features of these machines.



Electric Log Handler

A 25-ton capacity electric log stacker, capable of lifting entire truck-loads of logs at one bite, has been acquired by the Allison Lumber Co., Inc., Bellamy, Ala. In the company operation, trucks arrive at the mill at a rate of about one in nine minutes, and 200,000 board feet are moved each day either directly to the mill or decked in the storage area. The stacker, built by R. G. Letourneau, Inc., of Longview, Texas, delivers an average truck load of 14 tons to the mill in one minute.

Automatic Hydraulic Slab Saw

High speed hydraulic cut and feed with elimination of stalling are claimed for a new hydraulic slab saw introduced by Cornell Mfg. Co., Laceyville, Pa. The new saw cuts slabs up to 26 inches wide, 10 inches deep, and adjusts to cut lengths from 6 to 24 inches. With a discharge end extension, lengths of 4 feet and more are handled. Valve features permit adjustment of cutting and return stroke speeds. Saw requires 10 to 15 hp. and uses a 30-inch, 10-gage special tooth saw at 1600 RPM.

Waste Material Burner

A prefabricated refuse burner of aluminized steel said to resist rust and other forms of corrosion has been designed with special doors that permit trucks to dump refuse directly into the burner. Waste materials may also be fed by conveyor system, dust collecting system, or manually. Wilco Machine Works, Inc., Municipal Airport, Memphis 14, Tenn., manufacture the burner in ten sizes ranging from 15 feet in diameter upwards.

New Hardwood Plywood Booklet

The Hardwood Plywood Institute announces a 71 page pocket-size compilation of basic grade-use data and other information relative to sales or production of hardwood plywood. The "Faces, Figures, Facts" booklet includes photos of 18 different uses of plywood; descriptions of fixe different grades; and photos and price information on some 20 classes and species of material. Single copies are available on request to: Hardwood Plywood Institute, 2310 South Walter Reed Drive, Arlington 6, Virginia.

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EMPLOYMENT Opportunities

Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Employment Wanted

570—Age 27. Will receive Bachelor's Degree in Wood Products Merchandising from N. C. State College on 8/27/59. Desires Southern location. Prefers sales work. (Sept.)

573—Position desired in marketing or management in the particle board industry with 8 yrs. of experience in quality control, product research and production in the particle board, hardboard and lumber industries. Holds B.S. degree in Wood Products with 5½ yrs. College. (Sept.)

574—Chemistry-engineering combination. 6 years experience in chemistry; 5 in engineering with industry. Holds degrees in chemistry and biology, plus graduate credits. Now located midwest. (Oct.)

576—Production Mgmt. or product development in plywood, particle board, etc. Also sales promotion. Two years experience in plywood production, Calif. BS. in Forest Products, U. of Washington. Prefers Coast but will consider elsewhere. (Oct.)

577—Avail. Jan. 1. Finishing M.S. in forest products chemistry. Some experience in pulp and paper research. Courses or experience in ultra-violet and infra-red spectrophotometry, microscopy, ion-exchange chromatography. Desires position in chemistry, preferably bark or lignin research and development. Age 27. Married. Locate anywhere. (Oct.)

Positions Offered

E 359—Semi-Technical Salesman to work in Northern California–Southern Oregon area calling on saw mills and other industries with national line of chemicals. Should have some sales experience and forestry or chemical background. Age 25 to 40. Salary plus incentive compensation. Please send resume and references. (Sept.)

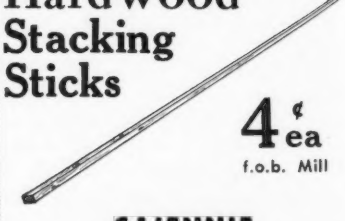
E 360—Association field representative. Wide range of work; some travel. Recent graduates in wood technology or forestry. Some experience. Job will provide experience in sales and technical consultation. South. (Oct.)

E 363—Sales reps. for hardboard manufacturer in Eastern half of U.S. Major firm; full benefits; experience desirable. (Oct.)

E 362—Michigan Case Goods plant seeks assistant to superintendent having considerable machine room production background and experience—permanent position with substantial opportunities for advancement. (Oct.)

(Advertisement)

One Car 5′ 10″ Hardwood Stacking Sticks



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FPRS FOREST PRODUCTS JOURNAL VOL. IX, NO. 9 SEPTEMBER, 1959

BACTERIAL ATTACK OF

Pine Logs in Pond Storage[1]

E. L. ELLWOOD AND B. A. ECKLUND
University of California Forest Products Laboratory, Richmond

Sapwood of pine logs stored in ponds may develop extensive porosity. Successful water treatments have disadvantages; pretreating logs didn't work. Decking logs under sprays is best until satisfactory treatments are developed.

Fig. 1.—Arrangement of 1000 gallon-capacity pond test cells with pump for filling the cells.

IN THE SPRING OF 1958, it was brought to the attention of the University of California Forest Products Laboratory that some difficulties were arising at manufacturing plants in the treatment of pine millwork with water-repellent preservative solutions (WRPS). In a typical case, all affected lumber had previously been stored as logs in a large pond. A considerable part of this lumber, when treated by the standard 3-minute immersion in WRPS, became completely saturated. Vacuum treatment did not overcome the difficulty.

In addition to heavy loss of treating solution and undesirable solvent odors from the treated lumber, painting and finishing were also affected, because the water-repellent solvent is a common solvent for most paints and finishes. Even one month after treatment, painting of the over-absorptive material (so-called "sinker stock") resulted in lifting and bubbling of the paint (Fig. 2). Further complications may also be expected with the development of prefinishing operations at sawmills. The effect of this deterioration on pulping has not yet been explored.

The Laboratory was asked to establish the cause of the excessive porosity of the lumber and to recommend control methods.

Conditions and Nature of Attack

Effect on Wood: Microscopic examination of excessively porous ponderosa and sugar pine sapwoods showed that only the ray tissue of sapwood was visibly affected. In moderately porous sapwood, all ray cell contents (mainly starch, as detected from KI staining) were depleted. In extremely porous sapwood, the thin-walled ray parenchyma cells were also destroyed (Figs. 3, 4), so that the porosity of the wood was greatly increased without a substantial decrease in strength. No deterioration of the tracheids (including ray tracheids) was observed.

Cause of Deterioration: Lindgren (6)[2], in studies on southern pine, has recorded similar symptoms as a result of attack by the mold fungi, *Trichoderma* spp. Microscopic inspection of the material involved in the present investigation, however, did not show active attack by this or any other fungus. Further, the virtually anaerobic conditions of pond storage are not favorable to fungal growth. On the other hand, large numbers of rod-shaped bacteria were observed in the affected wood; they were not apparent in sound wood.

At this point in the study, it was learned that Stutz and Stout (8), of the Western Pine Association, in investigations on brown stain some 18 months earlier, had attributed the cause of excessive porosity in pine sapwood to rod-shaped bacteria. Evidence from Dr. A. W. Stout, and subsequent investigations, indicated that bacterial attack occurred primarily in

[1] Presented at Session VII, Logging, FPRS 13th National Meeting, June 28–July 3, 1959, San Francisco, Calif.

[2] Numbers in parentheses refer to the Literature Cited at the end of this report.

The Authors: Eric Ellwood holds an MS from the University of Melbourne, Australia, and a PhD from Yale. He is chief of the Div. of Timber Physics and Mechanics at the California Laboratory.

Barton Ecklund holds a BS in wood technology from University of Michigan. He is a wood technologist at Laboratory.

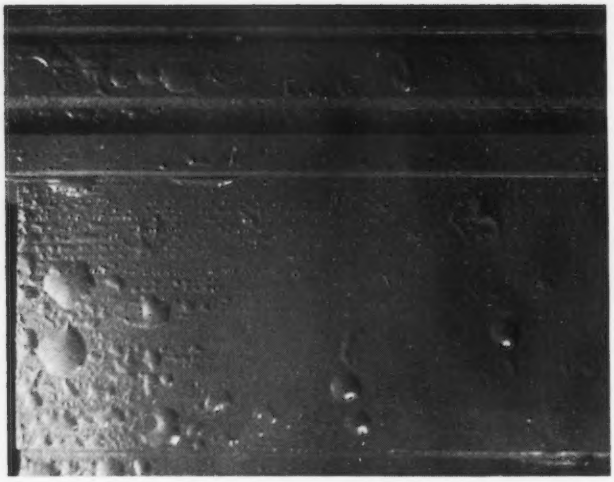

Fig. 2.—Blistering of paint on treated millwork caused by excessive retention of treating solution.

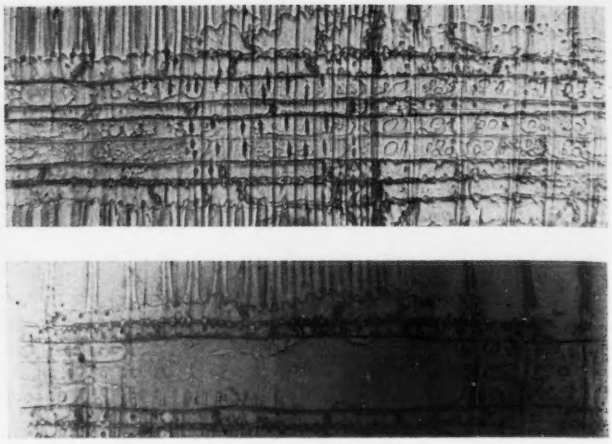

Fig. 3.—Photomicrographs of radial view of sound (top) and infected (bottom) P. ponderosa ray tissue. Severely infected ray tissue shows depletion of ray parenchyma cell contents and disintegration of ray parenchyma.

wood that was stored in stagnant ponds.

The identity of the bacteria was unknown but their deteriorating effect was apparently favored by anaerobic conditions. It seemed probable that excessive porosity found in the present instance was caused by the same type of organism as that found by the Western Pine Association.

The authors know of only two other recorded cases of possible bacterial effects on wood stored in water, both very recent. Findlay (5) refers to a bright orange stain in beech logs that were wholly submerged in a pond. Suolahti and Wallen (9) found that pine sapwood that had been stored wet for some time took up water readily after it was dried. They ascribed the increase in porosity to a decrease in pectin as the result of the action of micro-organisms.

Effect of Pond Storage Conditions: To relate the bacterial attack to pond storage conditions, three separate lots of ponderosa and sugar pine logs were removed from a large, stagnant millpond, and cross sections of the logs were examined. Material was also obtained from fresh non-ponded logs and from logs decked under sprays. The cross sections were oven-dried and then dipped in water-repellent solution to determine the extent of porosity.

The cross sections were from the following material: (a) sound and salvage logs that had been felled not more than two weeks before inspection, and were not ponded; (b) ponded logs that rested on the top of the log bundle and clear of the water; (c) logs partially immersed in water by virtue of their position in the log bundle; (d) logs that had been completely immersed in the pond water for periods of 7 to 10 days, two months, and one year, respectively; and (e) logs that had been decked under sprays for three months. At the same time, samples of pond water were taken for analysis of organic matter, oxygen, and bacterial content.

The examination showed no excessive sapwood porosity in fresh and salvage unponded logs, nor in ponded logs that were resting clear of water on the tops of bundles. The sapwood of logs stored in decks under sprays was also sound. No bacteria were evident in moisture expressed from these samples.

The cross sections taken from the centers of 32-foot logs of sugar and ponderosa pine showed high porosity in sapwood that had been completely immersed for 7 to 10 days. Bacteria were also present. All material that had been completely immersed for two months or more showed extremely high porosity in the center cross section of the log sapwood, together with a high bacterial content.

The logs that were partially immersed in pond water showed very high porosity in all completely immersed sapwood, but very slight evidence of attack in sapwood above the water line. Fig. 5 shows the relatively sharp demarcation between porous and non-porous sapwood at the water line. As with previous tests, no bacteria were found in the non-porous portions of sapwood in these logs, although large numbers were found in the very porous sections.

Examination for variation of infestation along the length of the log showed that, apart from somewhat heavier attack at the very ends, the infestation appeared fairly uniform throughout the length. Usually the very porous areas in the wood first appeared as pie-shaped, radial zones that gradually extended over the whole of the sapwood (Fig. 6) as attack became more severe. This appearance suggested that penetration of the bacteria into the log could occur radially, probably through fissures in the bark and bruised areas, as well as longitudinally.

Apart from a strong (and offensive) sour smell of the green infected wood, no macroscopic evidence of attack was apparent in the logs in either the green or dried condition. The most satisfactory method found for determining the extent of infected wood was to dip the material in a light oil for a few seconds. The porous areas were immediately stained by the absorbed oil.

Determination of dissolved oxygen content showed it to be extremely low (0.0 to 0.8 ppm), which is a virtually anaerobic condition.

A standard plate count yielded the high value of 290,000 bacteria per cc. of water. An analysis of pond water made by the Department of Public

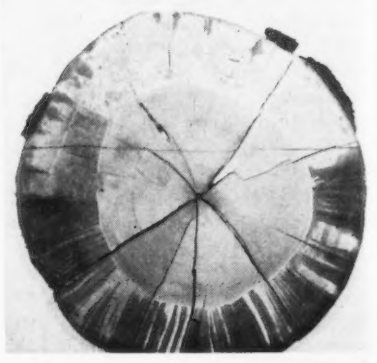

Fig. 5.—Cross section of ponderosa pine log that was partially immersed in pond during storage. Excessive sapwood porosity developed in the lower two-thirds of the log, which was completely immersed in pond water.

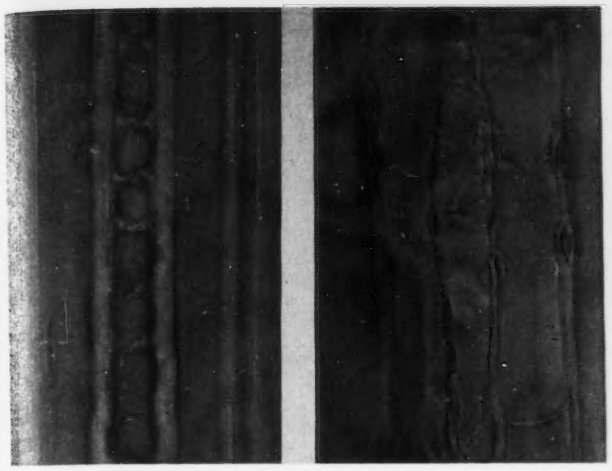

Fig. 4.—Photomicrographs of tangential view of sound and infected P. ponderosa ray tissue. Left normal ray tissue; Right: severely infected wood showing disintegration of ray parenchyma.

Fig. 6.—Cross sections cut from logs immersed in pond water for 3 weeks. The excessively porous sapwood shows as darkly stained wood as a result of heavy adsorption of water-repellent solution. In comparison, the section in the lower central position shows normal, uninfected wood that was not ponded.

Health, University of California, follows:

Chemical	mg./1.
hardness	61.0
carbonate	0.0
chloride	42.0
sulfate	2.1
calcium	18.0
magnesium	0.0
potassium	13.0
sodium	40.0
suspended solids	38.0
volatile suspended solids	37.0
soluble solids	326.0
volatile soluble solids	127.0
R_2O_3	16.4

The pH of the water was 6.8.

It was concluded that: (a) bacteria were probably responsible for the deterioration; (b) bacteria caused deterioration only under virtually anaerobic conditions such as existed in the pond water; (c) the logs were probably being infected by the high bacterial population already present in the pond water; (d) sufficient organic material was present in the water to enable rapid development of the bacteria; and (e) the fact that attack apparently occurs only under virtually anaerobic, wet conditions provides a partial explanation as to why complaints arising from "sinker" millwork have become more frequent in recent years.

Over the years, the increasing need to reduce water waste and pollution has probably caused a decline in the number of log ponds through which fresh water runs, while, at the same time, the use of water-repellent treatments has increased. The combination of these factors has produced the problem of excessive porosity in millwork.

Experimental Approach

A method of controlling the bacterial activity was sought at the request of one company concerned with the infestation. Consultations were held with Dr. Stout of the Western Pine Association, plant pathologists, bacteriologists, and water-treatment specialists. As a first approach, it was decided to undertake water-treatment tests to obtain control of bacterial action, and to proceed concurrently with attempts to identify the causative bacteria, so that accelerated toxicity tests and control methods could be tested on pure cultures in the Laboratory.

The direct control measures considered were: (a) chemical treatment of the pond water itself; (b) physical treatments, such as control by aeration and temperature; (c) treatment of logs before they were ponded; (d) introduction of microorganisms that are antagonistic to causative bacteria; and (e) recirculation of pond water by pumping in conjunction with filtration, chemical treatment, or both.

Alternative (e) was regarded as a "last resort" type of treatment because of the relatively high cost of establishing and operating such a system. No experimental work was done on alternative (d).

In this study, the main emphasis was given to alternative (a) on the basis that over-all treatment cost would be at a minimum if an inexpensive chemical with residual toxicity could be introduced into the pond water.

Water Treatment and Wood Pretreatment Tests

Test Methods: To evaluate the effect of chemical treatments on the activity of the causative bacteria in the pond water, two series of tests were set up. The first consisted of laboratory screening tests designed to select those chemicals that controlled the activity of the bacteria. The second series were larger scale tests in the pond itself, designed to evaluate the more promising laboratory treatments in a situation similar to field conditions.

1. Laboratory screening tests: Freshly cut blocks of sound *Pinus ponderosa* sapwood, 1 by 2 by 5 inches, were prepared from logs that had been recently felled and that had not come in contact with pond water. Duplicate chemical treatments were applied in aliquots of pond-water samples, of which 700 cc. were then placed in 1-quart Mason jars with perforated lids. Samples of water for the test were periodically obtained from the pond. Five hours after water treatment, one wood block was immersed in each jar of treated water, and the jar was then kept at 90° F. and 90 per cent relative humidity. Fig. 7 shows the laboratory screening test jar arrangement. The wood samples were removed from the water at approximately one-week intervals, at which times a 1-inch cross section was cut from the lower end of each block, the remainder being returned to the jars for subsequent sampling. The sample cross sections were immediately oven-dried and then immersed for 30 seconds in a water-repellent solution. The percentage absorption of water-repellent solution indicated the degree of porosity de-

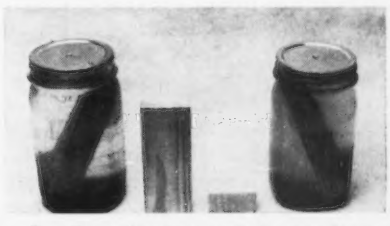

Fig. 7.—Laboratory screening-test jar arrangement, showing complete sapwood specimen and 1-inch-long section that was removed from the specimen at intervals for examination of porosity.

veloped, and therefore the degree of activity of the causative bacteria. As some contamination of the blocks with bacteria was common when the cross sections were cut from them during the test, an indication of the ability of the chemical water treatment to protect against recontamination was also provided.

In all screening tests, two types of controls were used. In one control treatment, the Mason jar containing wood blocks immersed in pond water was immediately sterilized in an autoclave for 20 minutes at 15 psi, then sealed. In the other control treatment, sound wood blocks were immersed in untreated pond water to provide a measure of the extent of porosity developed under the conditions of test when no treatment chemicals were applied.

The chemicals used in laboratory screening tests were chosen to cover a range of both recognized bacteriostats and several other treatments suggested by various authorities.

2. Pond cell tests: To evaluate treatments on a larger scale and under conditions more nearly approaching those of field use, eleven 1,000-gallon-capacity cells were constructed in the pond. Each cell consisted of two layers of plastic sheeting protected by a canvas layer around the plastic. The cells were 10 feet deep, with a cross section 2 feet 6 inches by 6 feet. The construction was arranged so that the opening of each cell was supported by a wooden frame attached to a balsa raft floating on the pond. The plastic bags were inserted through central openings in the rafts, and filled with 1,000 gallons of pond water by means of a metered pump. The arrangement of the pond cells and the method of filling are shown in Fig. 1.

By this test arrangement it was possible to include effects of pond depth, temperature variations, and proportion of wood to water, but not the influence of contact with soil or debris on the bottom of the pond.

Different chemical treatments were applied to the 1,000 gallons of water in each cell, and the cell contents were tested for uniformity of composition before the inclusion of test blocks. The elapsed time between treatment of cell water and inclusion of test blocks was normally 12 hours. The test blocks consisted of 1-foot lengths sawn from freshly cut, 12-inch- diameter *Pinus ponderosa* logs that had not been ponded. Random allocation of blocks to individual cells was adopted, with the inclusion of several blocks in each cell. Matched blocks were suspended in the adjacent, untreated pond water as controls. At intervals from one week to one month, blocks were removed from each cell and from the pond and sent to the laboratory for evaluation of porosity by the oven-drying and dipping technique.

3. Pretreatment of material before immersion in pond water: To evaluate the effects of diptreating the wood before immersion in infected pond water, 1 by 2 by 5 inch samples of green *Pinus ponderosa* sapwood were treated by different methods and then immersed in jars containing 1 gallon of pond water.

Because of the relatively high proportion of wood to water in the jars, as compared with conditions in the pond, one group of samples was surface-washed after treatment. By this means, the concentration of chemical applied to the water was reduced. In this screening test, it was realized that, if satisfactory control of bacterial activity were obtained, the results would need to be checked by immersing pretreated logs in a much larger volume of water to obtain a more realistic appraisal.

Successful laboratory jar pretreatments were subsequently tested on a larger scale by pretreating log sections before they were ponded. Two-foot-long sections from freshly cut *Pinus ponderosa* logs were dipped in solutions of chemicals before immersion in the pond. In some cases, strips of bark were removed after the sections were dipped to simulate conditions that normally arise in handling, strapping, and moving logs around the pond.

Untreated and treated cross sections of the logs were suspended in the pond. To determine the variation in the rate of porosity development over several months, fresh, untreated control samples were periodically placed in the pond.

For both the laboratory-jar and pond-immersion tests, wood porosity was determined at intervals of approximately one week by oven-drying and dipping treated samples.

Results and Discussion of Water Treatment Tests

1. Laboratory screening tests: Approximately 150 laboratory screening tests were made on various chemicals. It was anticipated that they would have some bacteriostatic effect either by acting on the bacteria themselves or by affecting the enzyme system.

Because relatively large volumes of water are involved, any economically attractive chemical treatment of the water required that the chemical added should be cheap and effective in relatively few parts per million. The maximum concentrations of the chemicals used in the tests were therefore restricted by economic considerations.

Table 1 shows those treatments that had some effect in retarding or controlling the development of porosity. It may be seen from the table that, while a number of chemicals provided complete control for a short period, the majority were ineffective after the blocks were immersed in the water for one month.

The only treatments that prevented attack for one month at relatively low concentrations were: 10 ppm of pentachlorophenol plus 100 ppm of detergent; 10 ppm of sodium pentachlorophenate; 5 ppm of an organic mercurial (Panogen); acidification to pH 2.0–3.0 with various acids; increase of alkalinity to pH 10.5; and flocculation with aluminum sulfate.

At considerably higher concentrations, 10,000 ppm of 30 per cent hydrogen peroxide, 20,000 ppm of sodium chloride, 50,000 ppm of sulfite waste liquor, and 50,000 ppm of tannic acid were effective for the duration of the test.

Of these treatments, no further work was done on the organic mercurials because of the question of toxic hazard. The alkaline treatments were discarded because of the resultant darkening of the wood. Tests that were continued at the pond cell scale were reduced to sodium pentachlorophenate, acidification with sulfuric acid (the cheapest acid available) and hydrochloric acid, and flocculation with aluminum sulfate. Although the amount of sodium chloride required was large, this test was also continued because of the low cost of salt.

Additional treatments that resulted in no apparent control are shown in Table 2. In this connection, additional tests were made with calcium hypochlorite, a recognized water-treating chemical, to ascertain the amount necessary to maintain chlorine residuals in the water. It was found that the consumption of chlorine by organic matter in the water, including logs, was so great that chlorine treatments were not economically feasible.

During the tests it became apparent that the technique of removing a portion of each test block for examination resulted in re-infection of the blocks. This was most apparent in the treatments in which the pond water was heated before immersion of the test blocks. In all cases where the water was heated to 160° F. or more, complete control was obtained for the first week. After each block was cut, however, attack occurred in the block after it was replaced in the jar. This behavior indicates that rapid development of the causative organism is possible, and that any treating method would, of necessity, need to have a fairly long residual effect to be economically feasible. The laboratory jar screening test

provided a measure of effectiveness against recontamination of the water or wood as well as a measure of initial control of the causative organisms.

2. *Pond cell tests:* The results of the pond cell tests are shown in Table 3. While several treatments showed some control for one week only, two treatments, namely acidification with sulfuric acid to pH 2.5 and sodium chloride, were effective for the duration of the tests.

Subsequent long-term tests were set up to test the duration of effectiveness of both these treatments as well as of aluminum sulfate at 250 ppm. To date, acidification to pH 2.5 with sulfuric acid has proved completely effective for two months. The long-term test cell containing sodium chloride was damaged during this test with resultant loss of salt and attack of the log sections. However, subsequent long-term laboratory jar tests with salt still show effective control after a six-month period.

Although at this stage no data are available on the possible absorption of acid by pond bottom debris and soil, the amount of concentrated sulfuric required to acidify pond water containing logs was 4,595 lb. per million gallons of water. Conductometric-potentiometric titration of the pond water showed that the water was slightly buffered above pH 4.4. The effect of buffering on acid requirements was therefore comparatively slight. If a price of $20 per ton of acid is assumed, the total cost of chemical for this treatment is approximately $46 per million gallons of water. Cheaper sources of acid, such as waste products, are probably also available. The cost of salt ($6 per ton) in general would be prohibitive at $498 per million gallons, but the control obtained indicated that storage in sea water would be effective.

Although the cost of sulfuric acid for control makes its use economically feasible, this chemical has some disadvantages. With respect to corrosive effects on metal, corrosion is accelerated below pH 6. Corrosion tests on metal strips placed in acidified pond water indicated that corrosion rate was approximately double that in non-acidified pond water. With regard to corrosion effects in the mill, however, it is believed that washing and debarking of the logs would remove most of the free acid and thereby reduce the corrosion hazard to a very low value.

The presence of sulfates can cause deterioration of concrete footings immersed in acidified water. The action occurs relatively slowly, and sulfate-resistant mixes are available with which it would be possible to sheath footings.

Table 1. TEST CHEMICALS SHOWING SOME BACTERIOSTATIC EFFECT IN LABORATORY JAR SCREENING TESTS

Chemical	Concentration ppm	Immersion period* One week	Four weeks
Chlorinated phenols:			
Pentachlorophenol	5	X	X
"	10	X	X
"	20	X	X
" 100 ppm detergent	10	O	O
Sodium pentachlorophenate	1 (penta)	X	XX
" "	10 "	O	O
Proprietary emulsion of pentachlorophenol	10 "	O	XX
" " "	25 "	O	XX
" " "	50 "	O	XX
Mercurials:			
Ethyl mercuric phosphate	0.5 (Hg)	O	XX
Panogen (methyl mercuric cyanamide diamide)	5	O	O
Quarternary ammonium compounds:			
Hyamine (50% alkyl tolyl methyl trimethyl ammonium chlorides)	20	X	XX
Oxidizing agents:			
Hydrogen peroxide (30%)	1000	O	XX
" "	10,000	O	O
Flocculating agents:			
Copper sulfate + 5 H_2O	15	X	XX
Aluminum sulfate + 18 H_2O	150	O	O
" " , filtered	150	O	XX
" " "	200	O	X
Aluminum ammonium sulfate+24 H_2O	225	O	X
Inorganic salts:			
Ferric chloride+ 6 H_2O	100	X	XX
Sodium nitrite	300	X	XX
Sodium sulfide + 9 H_2O	1000	X	XX
Sodium chloride	10,000	O	X
" "	20,000	O	O
Miscellaneous chemicals:			
Chloropicrin (trichloronitromethane)	5	O	XX
Sea water	100,000	X	X
Sulfite waste liquor	10,000	O	X
" " "	50,000	O	O
Sulfur dioxide	100	O	XX
Tannic acid	10,000	O	X
" "	50,000	O	O
pH control chemicals:			
Lime	to pH 10.5	O	O
Hydrochloric acid	to pH 2.7	O	O
Sulfuric acid	to pH 2.0	O	O
Nitric acid	to pH 2.0	O	XX
Perchloric acid	to pH 3.0	O	O
Trichloroacetic acid	to pH 3.0	O	O
Temperature control:			
140°F. for one hour		X	XX
160°F. for one minute		O	XX
160°F. for one hour		O	XX
212°F. for one minute		O	XX
212°F. for one hour		O	XX
Untreated control samples		XX	XX
Untreated sapwood blocks wrapped in aluminum foil and not immersed		O	O

* O = complete control; X = partial control; XX = no control.

Table 2. WATER TREATMENTS TESTED WHICH PROVIDE NO CONTROL AT THE MAXIMUM CONCENTRATION LISTED IN LABORATORY SCREENING TESTS

Treatment	Concentration of Chemical ppm
Methylisothiocyanate	20
Calcium hypochlorite	50
Hydrogen sulfide	to saturation
Sulfate pulp liquor	10,000
Sodium hydroxide	to pH 10.5
Ferrous sulfate	100
Copper sulfate	50

The toxic hazard of acidified pond water to workmen is not considered severe.

At this stage, although is has been shown that control of sapwood infestation can be achieved, the ideal chemical from the aspects of duration of effect, freedom from undesirable side effects, and attractive cost, remains to be found.

Results and Discussion of Wood Pretreatment Tests: Pretreatments and their effectiveness in the laboratory jar tests are shown in Table 4. Three pretreatments with hydrogen peroxide, formaldehyde, and sodium hydroxide were successful in preventing attack over a four-week period. Rinsing the samples with water after pretreatment and before immersion in the infected water did not alter the results. It is probable that the concentration of chemical used was sufficient to exert a bacteriostatic action on the infected water. Because formaldehyde caused darkening of the wood, only hydrogen peroxide and sodium hydroxide pretreatments were continued in pond tests with log bolts.

The results of the larger scale pond tests, in which the effect of the pretreatment chemical on pond water was absent, are shown in Table 5.

The only treatments that showed short-term control were those in which the bolts were placed in the pond without removal of a portion of bark. All treatments had completely failed at the end of the three-week test period. It is therefore apparent that a simple chemical pretreatment of the logs offers little opportunity for obtaining control. Abrasion of the log surface provides an opening after treatment, which would be a common entry path for the causative organisms. Even if some fixation of the treating chemical with the surface of the bark or wood occurred, the residual amount would be small because of the leaching action of the pond water.

Examination of the untreated control log sections that were periodically placed in the pond over an interval of several months showed considerable differences in the rate of porosity development. The rate was comparatively slow in the coldest season of the year with a pond water temperature of 57° F., and most rapid in the warmest season when the water temperature was at 91° F. This behavior was indicative of attack by a mesophilic organism.

Bacteriological Studies

Concurrently with the development of screening tests for evaluation of control methods, work was begun on the identification and occurrence of the causative bacteria. To undertake this phase of the work, a bacteriologist was employed for four months. Consultations were also held with Dr. E. McCoy of the Department of Bacteriology, University of Wisconsin, at the suggestion of Dr. Stout of the Western Pine Association, and with Dr. P. Ark of the Department of Plant Pathology, University of California, Berkeley.

Procedure: Initially, work centered around the development of techniques to permit production of pure cultures of bacteria from the infected wood and from the infected pond water. Distilled water and sterile pond water were then inoculated with the pure culture, and Mason-jar screening tests were made on sound wood blocks immersed in the inoculated water in a manner similar to that described for evaluation of bacteriostats.

Cultures from the water were made by the pour-plate method, with both nutrient agar and starch dextrose agar. The cultures were incubated both aerobically and anaerobically at 90° F. and 95 percent relative humidity. A wide variety of cultures was obtained.

Cultures of infected wood samples were made from moisture squeezed from the wood, and from wood chips. All cultures were grown in agar under both aerobic and anaerobic conditions. The squeezings and sawdust yielded a pseudomonas and some micrococci. The wood chip growth was more varied, and yielded gram-positive cocci, and rods that were gram-positive, gram-negative, and gram-variable.

Examination of the morphological characteristics of these cultures, microscopic examination of the bacteria, and specific tests on their carbohydrate reactions indicated that the most abundant bacteria were Bacillus species, some of which were tentatively identified as *B. cereus, B. macerans, B. megaterium,* and *B. polymyxa. Pseudomonas* sp. and *Sarcina* sp. were also present.

These cultures were triple-transferred to starch dextrose agar slants to ensure pure cultures. Distilled water, both sterilized and non-sterilized, and sterilized pond water, in jars, were then inoculated with the cultures and incubated at 90° F. for three days. All glass was sterilized in an autoclave prior to testing. Sterilization of pond and distilled water was accomplished by autoclaving for 30 minutes at 15 psi steam pressure. Complete sterilization of the wood blocks was achieved by the same schedule: for surface sterilization, the blocks were momentarily dipped in boiling water.

Sound *P. ponderosa* sapwood blocks, both sterilized and non-sterilized, were then immersed in the jars. The jars and contents were kept at 90° F. for one week before examination of the test blocks. The method of testing for attack of the wood was adsorption of water-repellent solution by the blocks after they were oven-dried.

Several series of these tests were made. They covered the cultures obtained from pond-water-infected wood and cultures of bacteria obtained from the California State Department of Public Health and from Dr. McCoy of the Department of Bacteriology, University of Wisconsin. The cultures obtained from the California State Department of Public Health were: *B. cereus* and *Pseudomonas* sp.; from Dr. McCoy, *B. polymyxa* (strains 50 and 510) and *B. macerans.*

In addition to tests of pure cultures in the jar-inoculation test, several mixtures of cultures were tested.

Cultures were also taken from sound, freshly felled logs cut from sound and salvage trees. Precautions were taken to minimize the possibility of infection after the trees were felled. Cross sections were cut from the trees along the log length and shipped directly to the laboratory, where wood chips were extracted from the center of the sections under aseptic conditions. Some gram-positive bacterial rods were obtained and tested against wood blocks.

Results of Laboratory Jar Tests on Development in Wood Blocks: Table 6 shows the extent of porosity developed in *P. ponderosa* sapwood blocks immersed in water inoculated with various cultures. Comparison of controls V, W, and X shows that sterilization treatment of the wood block before immersion resulted in slightly less porosity when the blocks were surface sterilized or partly sterilized. This behavior was in conformity with the laboratory screening tests for evaluation of bacteriostats, where porosity developed in non-sterilized, sound wood blocks immersed in sterilized distilled water. This indicates that apparently sound wood may contain bacteria that are capable of attacking the wood when it is stored under water. The development of the attack is very much slower than that obtained when the specimens are immersed in water containing a high count of bacteria, however, as shown by comparison of controls V, W, and X with control Y.

The most severe development of porosity was obtained with cultures B56, B100, *B. cereus,* and *B. poly-*

Table 3. POND CELL EVALUATION OF WATER TREATMENTS ON WOOD POROSITY

Chemical	Concentration ppm	Immersion period** One week	Four weeks
Chlorinated phenols:			
Sodium pentachlorophenate 150 ppm lime	150	O	X
" " " " " "			
plus 25 ppm detergent	25	X	XX
Flocculating agents:			
Aluminum sulfate + 18 H_2O	250	X	XX
pH control chemicals:			
Sulfuric acid	pH 2.5	O	O
" "	pH 3.0	X	X
Hydrochloric acid	pH 2.5	O	X
" "	pH 3.0	X	XX
Miscellaneous:			
Chloropicrin (trichloronitromethane)	5	O	XX
Mylone(3, 5-dimethyltetrahydro -1, 3-5, 2H- thiadiazine-2-thione)	5	X	XX
Sodium chloride	20,000	O	---*
Arsenic trioxide	5	X	XX
Sodium azide	2.5	XX	XX
Borax	150	XX	XX
Aeration (by air injection)	to saturation (6)	XX	XX

*cell damaged with loss of salt
** O = complete control; X = partial control; XX = no control

Table 4. LABORATORY SCREENING TEST RESULTS ON WOOD PRETREATMENTS*

Chemical applied to wood specimens before immersion in jars	Dipping time (minutes)	Immersion period** One week	Four weeks
30% formaldehyde	30	O	O
50% hydrogen peroxide	30	O	O
10% sodium hydroxide	30	O	O
Chlorine gas	5	X	X
Paraffin wax-coated samples	--	XX	XX
Untreated control samples	--	XX	XX

* Similar results were obtained when wood samples were rinsed with water after treatments and before immersion in pond water.

** O = complete control; X = partial control; XX = no control.

Table 5. EVALUATION OF WOOD PRETREATMENTS AT POND

Chemical applied to bolts before immersion	Dipping time	Partially debarked after dipping	Immersion period** One week	Three weeks
3% hydrogen peroxide	30 sec.		O	XX
" " "	30 sec.	*	X	XX
" " "	5 min.		O	XX
" " "	5 min.	*	X	XX
35% hydrogen peroxide	30 sec.		O	XX
" " "	30 sec.	*	X	XX
" " "	5 min.		O	XX
" " "	5 min.	*	X	XX
Untreated control sample	-------		XX	XX

* Strip of bark removed after dipping.

** O - complete control; X - partial control; XX - no control

myxa 30, for which the porosity approached or exceeded that developed in wood blocks immersed in untreated pond water (control Y). Although some increase in porosity was obtained in cultures B13, *B. macerans*, and *B. polymyxa* 510, the extent of the increase was within the range obtained from non-inoculated, sterile control treatments that were variously conducted throughout the investigation.

The active attack by culture B56 is a further indication that causative bacteria may occur in the living, sound tree as well as in the pond water. In this regard, the presence of bacteria in living bark and wood has been recorded by other investigators (2, 3, 4).

Table 7 shows the development of porosity as affected by sterilization of the sapwood blocks before immersion, and the influence of anaerobic conditions. In this test, one set of test jars was sealed with paraffin wax after immersion of the blocks. This was done more closely to approximate anaerobic conditions.

It may be seen from this test that: (a) no increase in porosity developed in sterilized sapwood blocks immersed in sterilized pond water under either aerobic or anaerobic conditions (cf. treatments A, C, I, and J); (b) porosity increased in non-sterilized blocks immersed in sterilized pond water under both anaerobic and aerobic conditions, with the increase being greater under anaerobic conditions (cf. treatments B, D, I, and J); (c) porosity substantially increased in sapwood blocks immersed in non-sterile pond water, with the increase being greater for the non-sterilized blocks and apparently independent of the conditions of aeration (cf. treatments E, F, G, H, I, and J); and (d) no abnormal porosity developed in either sterilized or non-sterilized sapwood that was wrapped in aluminum foil for the duration of the test.

The indications therefore are that (a) some causative bacteria exist in the wood and are capable of developing porosity in the wood when it is immersed in non-infected water, but not when stored wrapped; and (b) the rate of porosity development was not markedly affected by the differences in aeration obtained in the test by sealing the jars.

Determinative Tests on Isolated Bacteria: Determinative tests on carbohydrate reactions, as listed in Bergey's manual (1), were begun on pure cultures. From these tests, tentative identifications of the bacteria associated with the development of porosity were made (Table 8).

All these bacteria have been previously isolated from cellulosic mate-

rials (7), but none is known to cause degradation of cellulose. *B. polymyxa* is related to hemp-retting bacteria, and is capable of attacking hemicellulose and pectin. Since the *B. polymyxa* cultures caused the greatest increase in porosity on test blocks, it is reasonable to suppose that their action on wood substance may be primarily on the hemicellulose-rich, and pectin containing, compound middle lamella (10). Such an attack could then result in separation of the parenchyma cells and the disintegration of the soft ray tissue. The extractive carbohydrates in the sapwood ray cells provide an initial medium for establishment of micro-organisms. The strong, sour smell of infected lumber is caused by production of organic acids as a result of carbohydrate breakdown.

B. cereus must also be suspected, for although the strain isolated from fresh, non-ponded logs caused but slight increase in porosity, a pure culture obtained from another source caused relatively severe porosity.

B. megaterium is not recorded as attacking hemicellulose, and is a true aerobe. It is therefore unlikely that this species is responsible for the development of porosity under stagnant pond storage conditions. More extensive tests are required to confirm these findings.

Although relatively few organisms that caused porosity were isolated in these tests, it is entirely probable that a considerable group of similar organisms are involved. It is also likely that different strains of any particular organism may vary in their ability to act on wood.

The optimum temperature for development of most bacilli, including *B. polymyxa,* is 85°–95° F. (1). This could explain the exceedingly rapid development of porosity observed in summer months (water temperature, 91° F.) as compared with a rate approximately one-third as fast in winter months (water temperature, 58° F.). Also, there was some indication, from the survey of millponds, that at higher altitudes (and lower water temperatures) attack was less pronounced.

Because both *B. polymyxa* and *B. cereus* are spore formers and are widely distributed, it is apparent that any effective control method will necessitate treatments that are continuous in their inhibiting effect on vegetative growth, or are substantially long-term in their effectiveness. Otherwise, the bacterial population of ponds will quickly develop from spores.

Table 7. RETENTION OF WATER REPELLENT SOLUTION BY SOUND *P. ponderosa* SAPWOOD BLOCKS AFTER IMMERSION FOR ONE WEEK IN WATER

	Control treatments	Retention (per cent of OD wt.)
A	sterile pond water – sterile wood – aerobic	15.8
B	sterile pond water – non-sterile wood – aerobic	21.7
C	sterile pond water – sterile wood – anaerobic	14.9
D	sterile pond water – non-sterile wood – anaerobic	28.0
E	non-sterile pond water – sterile wood – aerobic	29.7
F	non-sterile pond water – non-sterile wood – aerobic	47.7
G	non-sterile pond water – sterile wood – anaerobic	31.5
H	non-sterile pond water – non-sterile wood – anaerobic	45.8
I	sterile wood not immersed	17.0
J	non-sterile wood not immersed	12.0

Table 9. PERCENT RETENTION OF WATER REPELLENT SOLUTION BY SOUND *P. ponderosa* SAPWOOD BLOCKS IMMERSED IN POND WATER FROM VARIOUS SOURCES

Source	One week immersion	Two weeks immersion
A	67	91
B	57	90
C	55	91
D	64	110
E	73	107
F	79	100
G	89	110
H	67	102
I (original test pond)	111	115
Control X (wood and water sterilized)	21	21

Survey of Porosity Development in Wood Immersed in Various Millpond Waters

Samples of water were collected from eight different millponds in addition to the original test pond. All ponds had continuous water make-up and overflow, but in no case was there rapid exchange of pond water. Sound, fresh *P. ponderosa* sapwood blocks were immersed in samples of the water from the various ponds, and maintained for one week, after which porosity was evaluated by adsorption of water-repellent solution as previously described. The results are shown in Table 9. It may be seen that, although some porosity developed in the blocks immersed in distilled water only, the bacterial activity was considerably greater in those blocks immersed in pond water. It was not possible to obtain log sections from all millponds, but material from two out of three ponds showed development of excessive porosity in the sapwood. In the case where no excessive porosity was observed in the pond-stored sapwood, the logs were generally not left in the pond for more than one week. It is apparent that bacterial attack of ponded logs, at least in the cases surveyed, is more the rule than the exception.

Conclusions and Current Status of the Investigations

1. Extreme porosity developed in the sapwood of ponderosa and sugar pine logs when they were pond-stored in virtually stagnant water. Only the immersed portions of the log were affected. The development of the porosity was most rapid under summer conditions when water temperature was 90° F. No excessive porosity was observed in logs from the same source after they had been decked under water sprays for a similar period.

2. A survey of several millponds in California showed that the occurrence of excessive porosity was widespread and varying in intensity, and depended mainly on the log storage period and the water temperatures.

3. Excessive porosity results in heavy over-adsorption of water-repellent preservatives used for treating millwork, with subsequent difficulties in painting and finishing. The effect of porosity on factory surface-finishing operations and pulping characteristics has not been investigated. The Western Pine Association has associated brown stain in ponderosa pine with organisms causing porosity.

4. The excessive porosity developed because of depletion of the content of ray parenchyma and the eventual disintegration of the parenchyma. There was no apparent strength loss of the wood as a result of the parenchyma disintegration.

5. Investigations on the identity of the causative organisms indicate that spore-forming, facultative, anaerobic bacteria cause destruction of the sapwood ray cells. These bacteria are common inhabitants of soil and water. Cultures isolated from infected wood and water were tested against sound sapwood, and determinative tests were made. Pure cultures of known bacteria obtained from other sources were also tested against sound sapwood. From these tests, the causative organisms were tentatively identified as *B. polymyxa,* although it is probable that a variety of other related species (such as *B. cereus*) are also involved.

6. *B. polymyxa* will attack hemicellulose and pectin, but not cellulose. The perferential attack on thin-walled parenchyma, particularly in the sapwood ray cells, can be explained on the basis of the decomposition of the hemicellulose-rich and pectin-containing compound middle lamella of the cell walls. The probable reasons why heartwood ray cells are not attacked are: a) lack of readily assimilated food, such as starch, in the ray cells; b) more impermeable structure; and c) presence of substantially more air in the heartwood.

7. At this stage of study, it is not clear why attack is apparently not severe in logs stored in decks under sprays or in rapidly flowing water. It is suggested that, under the above conditions, the most important factor concerned are: a) the lower temper-

Table 6. RETENTION OF WATER REPELLENT SOLUTION BY SOUND P. ponderosa SAPWOOD BLOCKS AFTER IMMERSION IN WATER INOCULATED WITH BACTERIAL CULTURES ISOLATED FROM VARIOUS SOURCES

Culture	Retention per cent	Culture	Retention per cent
B 13 A	38.8	B. macerans A	32.8
B	35.4	B	30.0
C	46.0	C	35.1
B 14 A	21.5	B. cereus A	75.0
B	18.8	B	60.1
C	15.0	C	37.1
B 25 A	16.9	B. polymyxa 30 A	60.9
B	20.5	B	76.9
C	15.7	C	53.8
B 56 A	83.5	B. polymyxa 510 A	35.6
B	88.3	B	31.7
C	55.0	C	39.7
B100 A	85.3	Pseudomonas sp. A	23.8
B	81.0	B	20.8
C	22.8	C	25.9
B105 A	14.7	Control V	19.2
B	14.6	Control W	18.5
C	14.6	Control X	13.3
		Control Y	62.0

Series A – Sterile distilled water and non-sterile wood blocks
B – Sterile distilled water and surface-sterilized wood blocks
C – Sterile pond water and sterile wood blocks

Control V – Sterile distilled water and non-sterile wood blocks
Control W – Sterile distilled water and surface-sterilized wood blocks
Control X – Sterile pond water and sterile wood blocks
Control Y – Non-sterile pond water and non-sterile wood blocks

Cultures B13, B14, B15, and B56 isolated from freshly cut trees that had not been ponded; B100 obtained from infected wood; B. cereus obtained from the California State Department of Public Health; B. macerans and B. polymyxa 30 and 510 obtained from the University of Wisconsin. Culture B105 was a spore-forming bacterium cultured from pond water previously acidified with H_2SO_4 to pH 2.5.

Table 8. TENTATIVE IDENTIFICATION OF BACTERIA ISOLATED FROM VARIOUS SOURCES (From microscopic examination, culture characteristics, and carbohydrate reactions)

Culture	Source	Species	Characteristics
B13	Freshly felled sound tree – not ponded	B. cereus	Gram positive – rod shaped facultative anaerobe with central ellipsoidal spores Widely distributed in solid, dust, milk, and plant surfaces.
B14	Freshly felled sound tree – not ponded	B. megaterium	Gram positive – rod shaped aerobe which does not grow in glucose broth under anaerobic conditions. Occurs widely in soil, water, dust, and decomposing materials.
B25	Freshly felled sound tree – not ponded	B. megaterium	See B14
B56	Freshly felled sound tree – not ponded	B. polymyxa	Gram variable – rod shaped facultatively anaerobic with ellipsoidal central spores. Hemicellulose and pectin attacked. Optimum temperature for growth between 85°–95°F. Widely distributed in soil, water, milk, feces, and decaying vegetables; is associated with retting of hemp.
B100	From infected wood	B. polymyxa	See B56
B105	From infected pond water	B. megaterium	See B14

tures of logs; and b) a low population of bacteria surrounding the logs. Because the bacteria can develop readily under aerobic conditions, and little penetration of air or oxygen can occur through a bark-covered log, it is unlikely that aeration of the surrounding water would provide control if bacteria were present in the wood.

8. Some evidence was obtained that causative bacteria were present in small numbers in apparently sound, freshly felled logs before they were ponded. Although the possibility of contamination after felling cannot be entirely disregarded, the evidence is that: a) a pure culture obtained from a freshly felled tree caused excessive porosity in apparently sound wood in laboratory jar tests although precautions were taken to prevent contamination from the time of felling; b) the development of porosity in sterilized sapwood was always considerably slower than that in non-sterilized wood when exposed to infected water; and c) apparently sound, freshly felled sapwood eventually developed excessive porosity when placed in sterilized water under laboratory conditions, whereas sterilized wood in sterilized water was not affected.

9. Treatment of pond water with chemicals, by aeration, and by heating showed that the development of porosity can be prevented for substantial periods by the addition of certain chemicals to the pond water. Some of these treatments were impracticable because they either involved the use of chemicals highly toxic to humans, or caused darkening of the wood. The most satisfactory treatment found so far, from the aspects of cost of chemical and duration of effect, was acidification to pH 2.5 with sulfuric acid. This treatment, however, has certain disadvantages.

At this stage, the ideal water-treating chemical remains to be found. Where mills are situated on coastal sites, storage of logs in salt water should prevent deterioration.

10. Although some causative bacteria may already be present in the logs before they are ponded, the bulk of the attack is from bacteria contained in the surrounding water, as shown by the progressive development of porosity from outside to inside of the sapwood. Since chemicals applied to the pond water can control attack, and do not substantially penetrate bark-covered logs, the most important infestation occurs in the log pond.

11. At the present stage, for those plants that require additional log storage facilities, decking of logs under water sprays appears to be the most practicable method of overcoming development of excessive porosity in pine sapwood. For those plants that already have large investments in pond storage facilities, control of the causative bacteria in the millpond is a necessity. More intensive cooperative investigations on screening tests of bacteriostats are continuing at the University of Wisconsin Alumni Research Foundation. The U. S. Forest Products Laboratory is also investigating the problem. In addition, the Western Pine Association has initiated investigations at the University of Wisconsin Department of Bacteriology. It is hoped that a more satisfactory control method may be evolved

from these studies, without recourse to pumping in conjunction with filtration or chemical treatment of pond water, or both.

Literature Cited

1. Breed, R. S., E. G. D. Murray, and A. D. Hitchens. 1957. Bergey's manual of determinative bacteriology (7th ed.). Baltimore, William & Wilkins Co.
2. Clausen, V. H., L. N. Rees, and F. H. Kaufert. 1949. Development of collapse in aspen lumber. Proc., National Meeting, FPRS.
3. Day, W. 1958. The distribution of mycelia in European larch bark in relation to the development of canker. Forestry (Gr. Br.) Vol. 31 (1).
4. Fidalgo, O. 1956. Tilose em Impomoea stipulacea provocada par bacterias endobianticas. Agr: Serv flor Brasil 10: 124–31.
5. Findlay, W. P. K. 1959. Sapstain of timber. For. Abs. 2 (20).
6. Lindgren, R. M. 1952. Permeability of southern pine as affected by mold and other fungus infection. Proc., Amer. Wood Pres. Assoc. 48.
7. Siu, R. G. H. 1951. Microbial decomposition of cellulose. N. Y., Reinhold Pub. Corp.
8. Stutz, R. E., and A. W. Stout. 1957. The nature of brown stains in timber from the western pines. Proc., Plant Phys. Meeting. Plant Phys. 32, Supp. (Aug. 25).
9. Soulahti, O., and A. Wallen. 1958 Der Einfluss der Nasslagerung auf dem Wasseraufnahmeverogen des Kiefsplintholzes. Holz als Roh u. Werkstoff 16 (1).
10. Wise, L. E., and E. C. Jahn. 1952 Wood chemistry (2nd ed). N. Y Reinhold Pub. Corp.

EFFECT OF DRYER TEMPERATURES ON

Bending Strength of Douglas-Fir Veneers[1]

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Douglas-fir heartwood veneers from 0.025 to 0.140 inch thick were dried and over-dried at temperatures from 225° to 450° F. Effects of drying temperature, drying time, and veneer thickness on modulus of rupture is reported. Strength was seriously reduced at 450°, but reduction was negligible at 375°. Although not statistically significant, strength of veneers is decreased by over-drying.

HEAT AFFECTS THE STRENGTH of wood in one or both of two ways. Firstly, there is a positive relationship between the temperature of wood and its strength properties; within certain ranges the hotter the wood the weaker it is, and the colder the stronger. Secondly, there is a permanent reduction in strength produced, presumably, by chemical degradation of the wood. Much of the information available about the effect of heat treatment upon the strength of wood, however, is not relevant to veneers dried at high temperatures and is not being reviewed.

Tiemann (30)[3] presented data to show that "when wood is re-dried after being subjected to saturated steam or air at 212°F. up to 8 hours, no appreciable reduction of strength occurred in compression or in bending (except in the case of red oak); but when re-soaked there was a very great reduction in these values as compared with the soaked controls."

McLean (18), working with 1/8-inch-thick specimens of several species, including Douglas-fir, at temperatures up to 320°F., concluded: "No important effect on any of the strength properties of the different species occurred when the wood was heated in the hot press or oven for 1/2 hour or less, even at a temperature of 320°F. Even in the longer heating periods up to 16 hours at 320°F., only the toughness and work-to-maximum load showed any marked reduction in comparison with the control specimens.

"Douglas-fir specimens heated in the hot press at 255°F. for periods up to 4 hours showed little reduction in any of the strength properties. Even after heating for 2 hours, test values for work-to-maximum load were over 90 percent of the control value. The other strength properties showed some increase after the wood was heated.

"Saturated steam at 320°F. affected the strength properties of the Douglas-fir to a greater extent than hot plates or the drying oven at the same temperatures and applied for the same period of 4 hours.

"In this connection, it should be noted that specimens heated in steam were at a moisture content as high or higher than the initial value of about 30 percent throughout the heating period; whereas those heated in the oven or the hot press dried quickly and were at a low moisture content for all but the first few minutes of the heating period.

"Douglas-fir (coast type) specimens heated in the oven at 215°F. for periods of 42, 100, 188, and 335 days showed a marked loss in strength properties especially in work-to-maximum load. In the longest heating period (335 days) strength values, adjusted to the moisture content of the control specimens, showed the following proportional values based on the strength of the control specimen: work-to-maximum load, 26 percent; modulus of rupture, 55 percent; modulus of elasticity, 83 percent; fiber stress at proportional limit, 67 percent;

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[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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"There was a reduction in most of the strength properties of the three species boiled in water for more than 8 hours, but the loss in strength was not marked even after heating for 64 hours. All three woods seemed to have a tendency to increase in specific gravity with increase in the boiling period, possibly because of some collapse or other conditions that caused more than normal shrinkage.

"A comparison of the results obtained with the different woods heated under the same conditions indicates there was little difference between the effects on the two hardwords, yellow birch and yellow-poplar, while Sitka spruce was somewhat less affected than Douglas-fir (coast type). The strength of Douglas-fir was apparently more affected by the heat treatments than the other species."

Kitahara and Chugenji (12) reported that the modulus of rupture (of Kinoki and Buna) was reduced 50 percent by heating for 5 hours at 200°C., but that the reduction was negligible for 5 hours at 150°C.

Northcott (24) determined: 1. "That the strength of Douglas-fir veneers is reduced by drying at excessively high temperatures. 2. That the strength of these veneers is reduced by drying for excessively long times at these high temperatures."

The property reported on in the above publication was the cleavage strength of blocks of wood one inch in the longitudinal and radial dimensions and 0.400 inch tangentially. The specimens were cleaved in the radial-longitudinal plane. With the breaking load of specimens dried at 225°F. taken as 100 percent, the following percentage reductions in strength were recorded:

Drying temperature, °F.	Drying time	Reduction in strength, percent
300	Just oven-dry	6.4
	O.D. + 60 min.	9.0
375	Just oven-dry	11.4
	O.D. + 60 min.	21.2
450	Just oven-dry	17.5
	O.D. + 60 min.	40.6

Evidence that the strength of wood can be seriously impaired by drying at excessively high temperatures suggests that plywood under certain conditions may have less than the anticipated strength. Common practice in estimating the load-carrying capacity of a plywood structure is to calculate the strength of plywood on the basis of the mechanical strength properties of clear wood as determined by established and accepted procedures. The wood from which these strength properties are obtained is air-dried under what are considered to be ideal conditions, so that any reduction in strength due to seasoning is minimized. The method of calculating plywood strength values, however, does not make allowance for strength reductions inherent in the method of drying the veneers, and hence this investigation on the effect of dryer temperatures on the static bending strength of Douglas-fir veneer.

Table 1.—ANALYSIS OF VARIANCE

Factor	Degrees of freedom	Sums of squares	Mean square	Divisor	Variance ratio
Error	896	1,933,798	2,158		
A	3	210,974	70,324	5,461	12.88***
B	3	23,644	7,881	5,461	1.44
C	3	147,327	49,109	16,174	3.03*
D	6	1,603,922	267,487	16,174	16.60***
AB	9	33,641	3,737	5,461	1
AC	9	25,139	2,793	5,461	1
AD	18	11,057	614	5,461	1
BC	9	5,742	638	5,461	1
BD	18	6,166	342	5,461	1
CD	18	291,145	16,174	5,461	2.9***
ABC	27	14,746	5,461	2,158	2.53***
ABD	54	23,050	426	2,158	1
ACD	54	36,193	670	2,158	1
BCD	54	25,323	469	2,158	1
ABCD	162	8,801	49	2,158	1

*Indicates significance at the p = .05 level.
**Indicates significance at the p = .01 level.
***Indicates significance at the p = .001 level.
p = probability.

Purpose of Study

The strength of plywood is determined partly by the strength of the veneers and partly by the strength of the glue bonds. The first step, therefore, was to investigate the strength of veneers in static bending with center loading.

The specific objectives were to determine the permanent effect on the bending strength of Douglas-fir veneers caused by:

1. The temperature at which veneer is dried within the range 225°F. to 450°F.
2. The length of time during which the wood is in the dryer.
3. The thickness of the veneer so that an estimate could be made of the strength of the surface layer of wood.

A factorial design was used that incorporated the following factors:

Factor A Four dryer temperatures: 225°, 300°, 375°, and 450°F.

Factor B Four times in the dryer: Just oven-dry, oven-dry plus 20 minutes, oven-dry plus 40 minutes, and oven-dry plus 60 minutes.

Factor C Four thicknesses of veneer: 0.025, 0.050, 0.100, and 0.140 inch.

Factor D Seven trees.

Specimens treated alike: Three specimens per tree per treatment combination.

Procedure

The procedure was as follows:

1. Edge-grain Douglas-fir heartwood cants 4 by 6 inches by 8 feet were selected.
2. The cants were heated to 180°F. in a water bath.
3. Veneers were sliced from the radial faces.
4. Veneers were stored under water until ready for drying.
5. Specimens 1 inch wide were sawn, with lengths along the grain being 2.9 inches for 0.025-inch-thick, 3.8 inches for 0.050-inch, 5.6 inches for 0.100-inch, and 7.0 inches for 0.140-inch-thick veneers.
6. Veneers were suspended from a balance while drying and weighed at regular intervals as drying proceeded. To facilitate the choice of the "just oven-dry" point, the oven-dry plus 60 minutes specimens were dried first, then, in order, the O.D. plus 40, O.D. plus 20, and finally the just oven-dry specimens.
7. Veneers were re-humidified to constant weight in an atmosphere of 70 ± 2°F. and 32 ± 2 percent relative humidity.
8. Before each specimen was tested, it was measured and re-weighed.
9. Specimens were tested in static bending with center loading over the following spans: for 0.025-inch veneers 1.9-inch span; for 0.050-inch veneers 2.8-inch span; for 0.100-inch veneers 4.6-inch span; and for 0.140-inch veneers 6.0-inch span.
10. Loads and deflections were measured until the elastic limit was exceeded after which the maximum load was recorded.

Results

The modulus of rupture results are presented graphically in Figures 1 to 10 inclusive.

Table 1 summarizes the analysis of variance.

Factor "A" (Temperature): Fig. 1 and Table 1 indicate that the strength (modulus of rupture) of Douglas-fir veneers was reduced by drying at temperatures in excess of 300°F.; the higher the temperature the greater the loss of strength. All trees reacted rather uniformly to drying temperature, as seen in Fig. 6.

The loss of strength at 375°F. was of minor importance, the modulus of rupture being reduced from 14,200 to 13,400 psi, or approximately 6 percent. At 450°F. the strength was reduced to 11,200 psi, a reduction of 21 percent, which could be quite serious.

Fig. 4 reveals that even at 450°F. the reduction in strength is not excessive provided the veneers are not

over-dried. Because veneers vary widely in the time required to dry them to a uniform moisture content, most veneers are over-dried in practice. It would not, therefore, be safe to assume that veneers dried at 450°F. in a commercial dryer suffer a negligible loss of strength.

Factor "B" (Time in the dryer): Figs. 2 and 8 indicate that the time the veneers are in the dryer is a factor that influences their strength; the greater the time the less the strength. It should be noted however, that the observed differences were not statistically significant.

Fig. 4 indicates that the reduction in strength due to over-drying is not great at 375°F., but that it can be serious at 450°F.

Factor "C" (Veneer thickness): This factor was included to obtain an estimate of the reduction in strength at the veneer surface. It was anticipated that the modulus of rupture would increase with an increase in veneer thickness such as occurred between 0.025- to 0.050- to 0.100-inch thicknesses. Extrapolating the curve through these points to zero thickness gave a figure of 9,200 psi for the modulus of rupture of the wood at the surface of the veneers. This amounts to a reduction of 35 percent, which seems sufficient to substantiate the theory that the strength of wood on the surface of veneer is degraded much more than that in the interior.

Fig. 5 indicates that the greatest reduction in strength occurred at the highest temperature. The rather large reductions also indicated at lower temperatures suggest that there may be contributing skin effects other than temperature, however, and lathe checks are suspected.

Factor "D" (Individual trees): Differences between trees are shown in Figs. 6, 8, 9 and 10. Veneer from different trees varied widely in strength—from less than 10,000 psi to more than 21,000 psi for modulus of rupture. Fig. 6 demonstrates that the strength of the wood from all 7 trees was severely degraded by a temperature of 450°F., while none was severely degraded at 375°F. In Fig. 8 it is seen that veneer from all trees tended to lose strength as the drying period was lengthened.

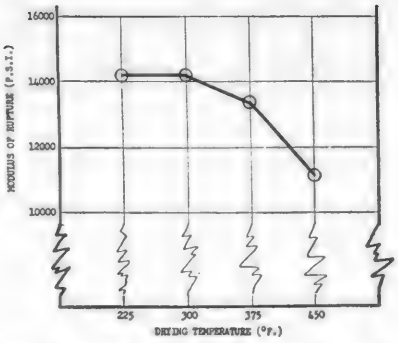

Fig. 1.—Effect of drying temperature (Factor A) on modulus of rupture.

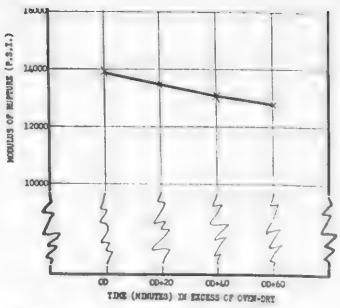

Fig. 2.—Effect of time in the dryer (Factor B) on modulus of rupture.

Lathe Checks

For the most part, these data conformed to an anticipated pattern. The variable relationship of individual trees to veneer thickness was unexpected, however. Only trees D and E followed the anticipated pattern. Trees B and F yielded most unexpected patterns, while most of the remainder were irregular.

In an attempt to discover the cause of this variability, the data included in Fig. 9, which averaged all temperatures and times, were broken down into temperature classes (see Fig. 10). In general the rather startling tree differences noted in Fig. 9 are repeated for each of the four temperatures. For instance, tree E showed the expected pattern of lowest modulus of rupture for the thinnest veneer and highest modulus of rupture for the thickest veneer, but tree B had its own peculiar pattern at all temperatures. Since these tree patterns seem to have been rather independent of temperatures, a search was made for possible sources of discrepancies. The 0.100- and 0.140-inch veneers of trees B, E, and F were inspected for lathe checks and other defects that did not result from the drying treatments. Tree B was chosen because of its peculiarly low strength in the 0.140-inch veneers, tree E because it followed the anticipated pattern through all thicknesses, and tree F because of its special peculiarities (though it did follow the anticipated pattern in the 0.100- and 0.140-inch thicknesses).

Table 2 summarizes the information regarding the lathe checks in the specimens from these trees, and estimates of the percentage by which the strength of the veneers are reduced by them are provided. Tree E, which followed the expected pattern, had relatively few shallow checks with a negligible weakening effect. Tree F, which in the two thicknesses examined followed the anticipated pattern, was rather severely checked, but both thicknesses were reduced in strength by practically the same percentage. Tree B, however, had unusually low strength in the 0.140-inch veneers, and the analysis indicated the 0.140-inch veneers to be much more severely weakened by the lathe checks than the 0.100-inch veneers. The figures are 38 and 17 percent reduction respectively for the 0.140- and 0.100-inch veneers.

It was thought that tree B might be eliminated from these analyses because of its abnormality—and possibly tree F—but inasmuch as these idiosyncracies did not seriously affect the temperature and time relationships, it was decided to include them. It is hoped that their inclusion will emphasize the great differences in lathe checks that may be expected in veneers of different thicknesses cut from the same tree, between veneers cut from different trees at one time, and between veneers cut on the same machine at different times.

Tiemann's findings (30) that strength was not greatly reduced by drying, but that subsequent soaking did seriously reduce the strength, are interpreted as a warning that the reduction in strength may be more serious than indicated in Figs. 1 to 10. It would be advisable to repeat a portion of this work, and to test specimens after successive cycles of soaking and drying, for the purpose of estimating the reduction in strength when panels are exposed to the weather.

Table 2.—LATHE CHECKS AND THEIR EFFECT ON THE STRENGTH OF VENEERS

Tree	B		E		F	
Veneer thickness (inch)	0.100	0.140	0.100	0.140	0.100	0.14
No. of checks per inch	14.5	17.8	7.6	8.0	10.5	15.6
Angle of checks to surface (degrees)	39.6	41.9	30.9	22.1	32.3	41.9
Percent depth of checks	34.4	41.5	13.2	12.3	41.4	32.9
Estimated percentage reduction in strength of veneer	17	38	2	4	23	22

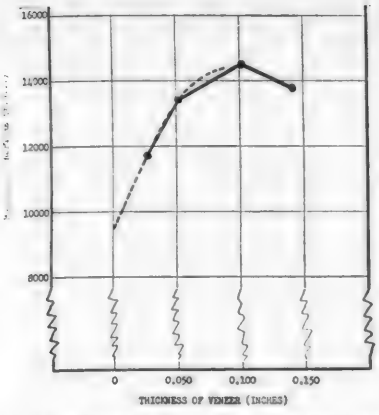

Fig. 3.—Effect of veneer thickness (Factor C) on modulus of rupture.

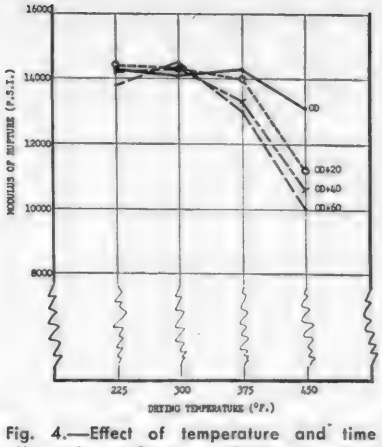

Fig. 4.—Effect of temperature and time (Interation AxB) on modulus of rupture

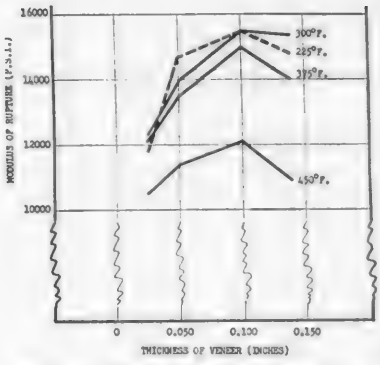

Fig. 5.—Effect of temperature and veneer thickness (Interaction AxC) on modulus of rupture.

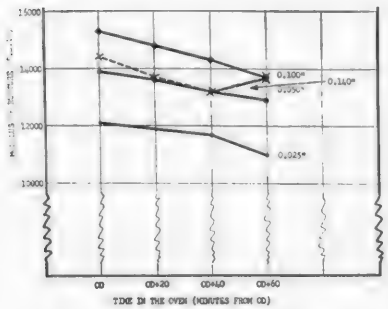

Fig. 7.—Effect of drying time and veneer thickness (Interaction BxC) on modulus of rupture.

Conclusions

The strength of Douglas-fir veneers, as measured by the modulus of rupture, is reduced by drying at excessively high temperatures. The effect is negligible at 375°F. but can be serious at 450°F.

The strength is reduced by overdrying veneers at excessively high temperatures, this effect often being serious at 450°F. but negligible at 375°F.

The strength of the cells on the surface of a veneer are degraded much more than those in the center of the veneer. Reduction of 35 percent in the strength of surface fibers was indicated.

When a study such as this one includes veneers that must be peeled from a number of trees in a variety of thicknesses at different times, the factors being studied can easily be confounded by the variability of the lathe checks from veneer to veneer through their effect upon the strength of the veneers. In such cases it would be prudent to eliminate specimens with abnormal lathe checks or to correct for them in the analysis.

Literature Cited

1. Alexander, J. B., and C. F. Archer. 1944. The effect of kiln-drying upon the strength of sitka spruce. Circular

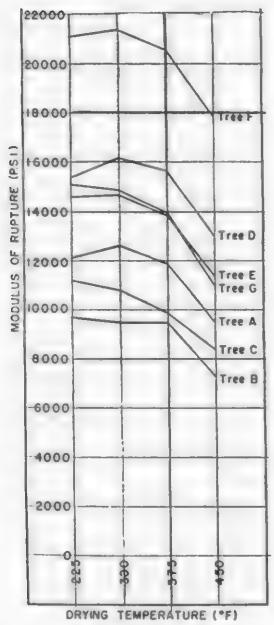

Fig. 6.—Effect of temperature and individual tree (Interaction AxD) on modulus of rupture.

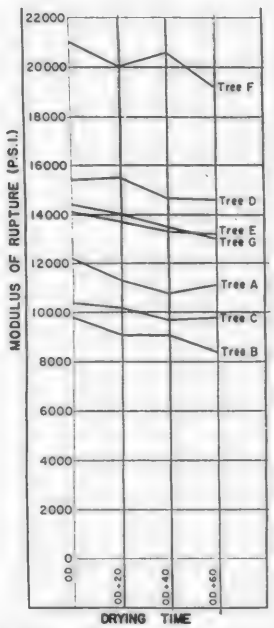

Fig. 8.—Effect of drying time and individual tree (Interaction BxD) on modulus of rupture.

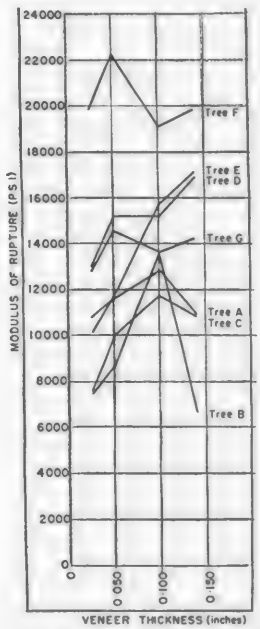

Fig. 9.—Effect of veneer thickness and individual tree (Interaction CxD) on modulus of rupture.

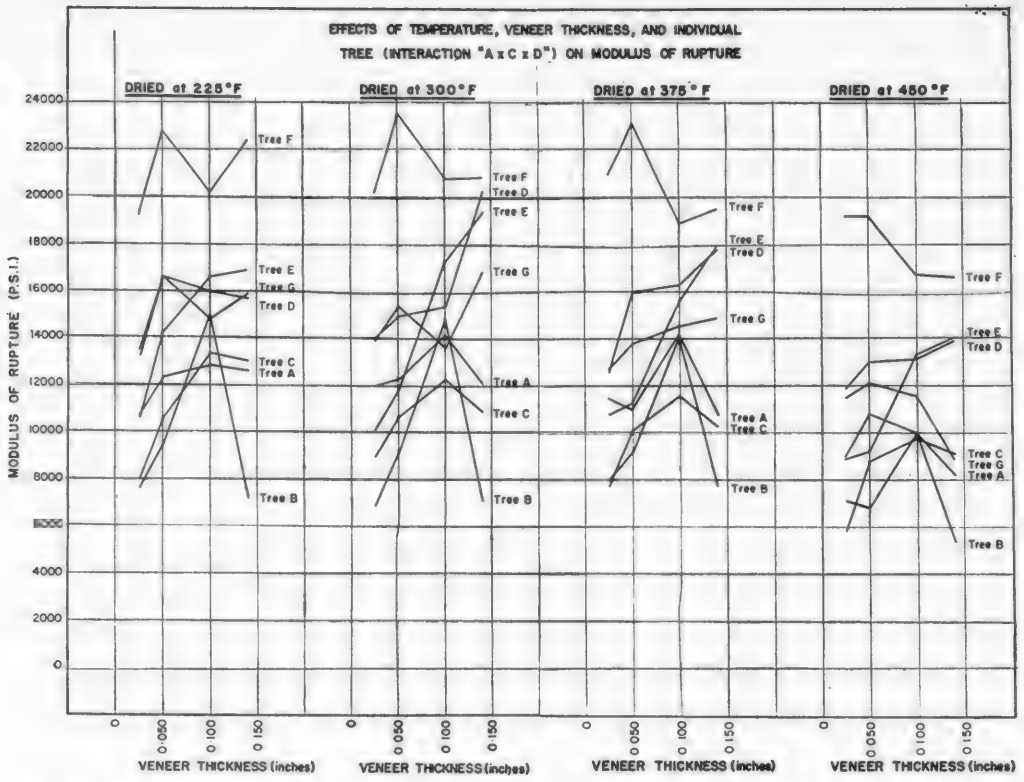

Fig. 10.—Effect of temperature, veneer thickness, and individual tree (Interaction AxCxD) on modulus of rupture.

No. 60. Forest Products Laboratories of Canada.

2. Alexander, J. B., and C. F. Archer. 1947. The effects of kiln-drying upon the strength of western hemlock. Circular No. 64. Forest Products Laboratories of Canada.
3. Boller, K. H. 1953. Wood at low temperatures. A paper delivered at the Low Temperature Symposium on Military Packaging Problems at the Quartermaster Food and Container Institute for the Armed Forces, Chicago.
4. Comben, J. A. 1955. The effect of high-temperature kiln-drying on the strength properties of timber. Wood (United Kingdom) 20 (8).
5. Currier, R. A. 1958. High Drying Temperatures—Do They Harm Douglas Fir Veneer? Forest Prod. J. VIII (4): 128.
6. Egner, Karl. 1952. The high-temperature drying of timber. Translation by Forest Research Institute, Rotorua, New Zealand, of a lecture given at the 18th Conference of the Swiss Association for Testing of Technical Materials (SVMT) at Zurich on Feb. 8, 1952.
7. Ellwood, E. L. 1953. Properties of beech in tension perpendicular to the grain and their relation to drying. Jour. of FPRS, Vol. 3, 1953.
8. Frashour, R. G., and R. A. Currier. 1956. Water absorption of Douglas-fir veneer dried at high temperatures. Oregon Forest Products Laboratory. Unpublished.
9. Graf, Otto, and Karl Egner. 1940. Translation by Bjarne Ulvestad, 1954. The strength properties of frozen and repeatedly frozen and thawed wood. Translation No. 141. U.S. Forest Products Laboratory, Madison, Wis.
10. Graham, R. D. 1957. Effect of several drying conditions on strength of coast-type Douglas-fir timbers. Forest Prod. J. VII, (7).
11. Grossman, P. V. A. 1953. The recovery of plywood after compression at elevated temperatures. Australian Journal of Applied Science, Vol. 4, No. 1.
12. Kitahara, K., and M. Chugenji. 1951. Effects of heat treatment on the mechanical properties of wood. Jour. Japan Forestry Society, Vol. 33.
13. Kitahara, K., and A. Suematsu. 1955. The influence of temperature on compressive properties of wood. Jour. Japan Wood Research Society. Vol. 1, No. 2.
14. Kohara, J., and H. Okamoto. 1955. Studies on the permanence of wood XVII. Increase of Young's modulus of bending by heat treatment. Jour. Japan Wood Research Society. Vol. 1, No. 2.
15. Kollman, Dr. F. 1940. (The mechanical properties of various moisture woods in temperature range from −200° to +200°C.) Die Menanischen Eigenschaften Verschieden Feuchter Holzer in Temperaturebereich van −200° Bis +200°C. published in Mitteilung qus dem Mechanish-Technologischen Institut der Reischsanstalt für Holzforschung zu Eberswalde. July-Aug. 1940.
16. Kollman, Dr. F. 1953. Translated by the C.S.I.R.O. Translation Panel, October, 1953. The dependence of some mechanical properties of woods on time, notching, and temperature. Translation No. 2017, Commonwealth of Australia, C.S.I.R.O.
17. Ladell, J. L. 1956. High temperature drying of yellow birth. Forest Prod. J. VI (11).
18. McLean, J. D. 1945. Effect of heat on the properties and serviceability of wood. Experiments on thin wood specimens. Report No. R1471. U.S. Forest Products Laboratory, Madison, Wis.
19. McLean, J. D. 1951. Rate of disintegration of wood under different heating conditions. American Wood Preservers' Assoc. Proc., Vol. 47.
20. McLean, J. D. 1953. Effect of steaming on the strength of wood. American Wood Preservers' Assoc. Proc., Vol. 49.
21. McLean, J. D. 1954. Effect of heating in water on the strength properties of wood. American Wood Preservers' Assoc. Proc., Vol. 50.
22. McLean, J. D. 1955. Effect of oven heating and hot-pressing on strength properties of wood. American Wood Preservers' Assoc. Proc., Vol. 51.
23. Mitchell, R. L., R. M. Seborg, and M. A. Millett. 1953. Effect of heat on the properties and chemical composition of Douglas-fir wood and its major components. Jour. FPRS, III (5).
24. Northcott, P. L. 1957. The effect of dryer temperatures upon the gluing properties of Douglas-fir veneer. Forest Prod. J. VIII (1).
25. Stamm, A. J., and E. E. Harris. 1953. Chemical processing of wood, Chapter V, New York, Chemical Publishing Co., Inc.
26. Stamm, A. J. 1956. Thermal degradation of wood and cellulose. Ind. Eng. Chem. 48, 413.

27. Stone, J. E. 1955. The rheology of cooked wood. TAPPI, Vol. 38 (8).
28. Sulzberger, P. H. (1948). 1953. The effect of temperature on the strength of wood, plywood and glued joints. Report ACA-46, Aeronautical Consultative Committee, Commonwealth of Australia.
29. Technical Committee of the West Coast Adhesive Manufacturers. 1956. Adhesive Manufacturers Status Report on Direct Fired Dryers. Unpublished.
30. Tiemann, H. D. 1944. What temperatures injure wood? Southern Lumberman, June 15.
31. Youngs, R. L. 1957. Mechanical properties of red oak related to drying. Forest Prod. J. VII (10).

Discussion

Tom McKenna (Monsanto Chemical Co.): Was all the veneer heartwood?

Mr. Fensom: Yes. (The paper was presented by Mr. Fensom, Superintendent of the Vancouver Lab.).

R. L. Youngs (U.S. Forest Products Lab.): Were any data obtained on the change in oven-dry weight with oven drying time?

Mr. Fensom: This information is available but was not analyzed. Data were analyzed to demonstrate difference in drying time due to drying temperature and differences between trees and within trees. I should say that, in theory, specimens were dried to a uniform moisture content, but actually the controlling factor was constant weight rather than uniform moisture content.

Mr. Youngs: How did final conditioned equilibrium moisture content vary with the time of drying?

Mr. Fensom: Specimens that were dried at high temperatures and for longer times had somewhat lower moisture content.

A. A. Marra (Simpson Timber Co.): The data presented are extremely interesting, particularly the extrapolations indicating the magnitude of the temperature effects at the extreme surface.

Mr. Fensom: The extrapolations were significant but not absolute.

Dr. Marra: As a means of verifying the trends observed with respect to surface damage, would it be possible to remove surface fibers after heat treatment in a suitably controlled experiment? This should produce a horizontal line with thickness if no other factors are interacting. If interactions do exist, their magnitude might thus be accounted to give a more absolute value for surface damage.

Mr. Fensom: It might be a useful project for the future to develop a technique that would enable this kind of testing to be done. It would appear that some type of non-destructive test would be required.

F. L. Brown (Dow Chemical Co.): What were the stress and strain rates in the tests? Were they controlled?

Mr. Fensom: The stress and strain rates were those specified in ASTM Standard D805–52, as follows: "the unit rate of fiber strain is equal to 0.0015 inch (0.04 mm) per inch of outer fiber length per minute with a permissible variation of ±25 percent."

Harold E. Worth (Bureau of Ships): Did the curves show an optimum strength for the veneer at each temperature—was a trend noted?

Mr. Fensom: A significant effect was not indicated by an analysis of variance. There was considerable variation between the test specimens from different trees.

Dr. James Bethel (N. C. State College): Do the authors intend to incorporate a regression analysis to re-evaluate the data of the experiment and gain more information?

Mr. Fensom: This would be useful data, but no such analysis is planned at the present time.

T. E. Batey, Jr. (Douglas Fir Plywood Assoc.): What was the veneer specimen orientation in testing with respect to lathe checks? Were the checks consistently on the compression face or the tension face of the specimen, or was control of this factor not included?

Mr. Fensom: The lathe checks were on the tension face of the specimens. In this connection it should be stated that only the horizontal checks were appraised in this study, since the vertical checks were not considered to have much stress effect. Apropos of this discussion on the drying of veneer I would iike to suggest that the overdrying of veneer might be reduced by sorting high and low floating logs, then sorting sapwood, heartwood, and mixed sapwood-heartwood veneer in both of these categories prior to drying. Since each of these six categories would presumably have a different average moisture content and specific gravity, more uniform moisture contents throughout any given production of veneer might be obtained by this additional sorting.

Dr. George Kitazawa: Conclusion number three seems open to question. The conclusion that the strength of cells on the surface of a veneer are degraded more than core does not appear to be substantiated by the experimental results, especially as there is no modulus of rupture versus veneer thickness relationships for temperatures below 225°F. I would suspect that one would obtain a curve similar to the family of curves in Fig. 5. If such a curve were found at the lower temperatures, conclusion No. 3 would be in error, because this would also mean that the curve extrapolated to "zero thickness" would give a skin strength below the core strength in terms of MOR, which would then eliminate temperature as a factor on the strength of veneer at or near the surface. I believe the difficulty in interpreting such data arises from the nature of the MOR equation itself, which is not a satisfactory index of mechanical properties because the area lying between the proportional limit and ultimate breaking load is so variable.

The authors have stated that the reduction of 35 percent in the strength of surface fibers was indicated and that this reduction came about primarily from the elevated temperature. They have, however, qualified this in the text in that there may be other contributing skin effects and possibly lathe checks, but still offer the temperature "hypothesis". It is quite possible that if absolute methods of determining strength could be employed for the surface and for the cores, there may exist significant differences. Unfortunately, the MOR computation is not a reliable tool for arriving at the differences since shear module, shifting of the neutral plane with thickness, and so forth, may be factors responsible for the shape of the curves. Since it is not easy to estimate these differences, the empirical approach is the obvious one.

To offer a better substantiation of the conclusion that temperature degrades the surface fibers (at the microscopic level and not at the macroscopic level, such as lathe checks, etc.), data on controls would be useful. For example, what would be the nature of the curves in Fig. 5 for 75°F. and 150°F.? If they are flat, then the author's conclusion is sound. If the curves are similar to the others, in that they drop off for decreasing thickness, then conclusion No. 3 is certainly not acceptable. I believe the only conclusion that one could draw from the latter possibility is that the MOR is reduced generally on both surface and in the core with temperature increase, but not necessarily at a quicker rate for the surface fibers. Further, the time in veneer drying would allow rapid equilibration of the temperature on the surface and in the center of the veneer.

In brief, the theory that fibers in veneer can degrade preferentially is not supported by the experimental data as it stands. To give further proof on conclusion No. 3, control curves would be essential.

Weight Losses of 40 Wood Species

EXPOSED TO PORIA INCRASSATA AND MERULIUS LACRYMANS[1]

J. D. Diller and E. J. Koch

Various wood species were exposed outdoors to: (1) determine and compare weight losses; and (2) demonstrate the test method.

Fig. 1.—The authors view an uncovered test plot with blocks in place. This site is typical of the 200 plots used to determine weight losses of woods exposed to the two destructive decay fungi.

Numerous reports are available in the literature concerning the relative resistance to decay of different wood species, as measured by various criteria. Lignum vitae, greenheart and Osage–orange have commonly been found to be most resistant. The relative resistance of numerous other species has not been consistent. This may be due partially to the lack of close comparisons of species for a single fungus infection. Tests comparing the relative weight loss caused by various wood-destroying fungus species in the field are also limited.

The objectives of this study were (a) to demonstrate a method of growing *Poria incrassata* (Berk. & Curt.) Burt., and *Merulius lacrymans* Fr. under outdoor conditions, (b) to compare the relative weight losses of the 23 native-grown woods exposed to these two fungi, and (c) to determine the relative weight losses of 40 wood species exposed to these fungi under outdoor conditions.

Test Fungi

In America, *Poria incrassata* is a spectacular destroyer of timbers in buildings, particularly in Southern and Pacific Coast States where mild, humid climates prevail. Despite wide distribution over the entire country, the occurrence of *P. incrassata* is relatively infrequent. During a period of approximately 25 years, forest pathologists in the South have reported only some 30 cases (9)[2]. The damage caused to buildings, however, is sometimes extensive and costly.

Merulius lacrymans is considered by European pathologists to be the most destructive wood-decay fungus in buildings. The fungus is always included as one of the test fungi in their laboratory studies (1). Although not indigenous, this fungus has been known to cause extensive damage in the United States.

Establishment of Test Plots

In the spring of 1951, the senior author observed the effect of ground covers on *Poria incrassata* in the crawl space of two basementless houses in Washington, D.C. Prior to the installation of the ground cover, the fungus had caused considerable damage to the subfloor timbers in the houses, both of which were less than 10 years old. Within a few weeks, the characteristic dull-white, coarse mycelial threads of the fungus had spread over most of the soil beneath the covers. This condition suggested a possible way of test-growing the fungi under outdoor conditions.

Each test plot was established by digging a shallow hole in the ground and placing in it infected wood scraps. The source of fungus inoculums was infected wood from buildings, since primary infections in buildings and lumber yards are assumed to stem from infected lumber.

A porous clay pot was inverted over the hole to simulate crawl-space conditions. At first a single thickness of 15-pound asphalt-saturated felt, 3 by 3 feet square, was placed over the inverted clay. Because the felt showed signs of deterioration after several months, a sheet of 4-mil polyethylene was placed under the felt. The polyethelene served as an effective moisture barrier during the remainder of the 2-year test period. Forest leaves were raked over the top as an additional insulation and moisture barrier against extremes in temperature and humidity. An old auto tire was put on top to hold the assembly in place. Additional leaves were added as needed. Occasionally during hot, dry summer periods, a gallon of water was poured about the clay pot.

Mean soil temperatures observed in the plots at monthly intervals during the first year closely approximated mean soil temperatures taken over a period of years in the crawl spaces of basementless houses in the Washington–Baltimore area.

As a protection against possible attack by termites and other wood-eating insects, the soil surface in each plot was given a single application of wettable 50 percent DDT spray at 250 pounds pressure about 6 months after

[1] A contributed paper, received September, 1958.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Author: Jesse Diller is Plant Pathologist, Northeastern Forest Experiment Station, U.S. Dept. of Ag., at Laurel, Maryland. E. James Koch is Statistician, Biometrical Services, Agricultural Research Service, U.S. Dept. of Agriculture, Beltsville, Maryland.

the plots were established. Previous experience with DDT in this form showed no apparent harmful effect on the fungi.

Possible contamination from other fungi introduced on the unsterilized wood-inoculum or present in the forest floor was recognized. Attempts to establish inoculants of other well-known species of wood-decay fungi under similar conditions led to poor growth or failure of the fungi to become established. This fact, plus the generally uniform appearance of the mycelial mats that developed on the test wedges, the characteristic diagnostic feature of cleavage-across-the-grain of infected wood, and the frequent identification of the test fungi from re-isolations, led the authors to conclude that the fungi grown were the ones specified.

One hundred test plots of each fungus were established during the winter of 1952–53 in a forested area near Beltsville, Maryland. Each plot was approximately 5 feet square. Plots of each fungus were arranged in four 25-plot blocks; the plots were 5 feet apart in each direction. The experiment was conducted during the 2-year period from August 4, 1953, to August 4, 1955.

Test Woods

Wood specimens were cut into uniform wedges, about 8 inches long and 2 by 2 inches square at the top. After the wedges were air dried to a uniform wood moisture of 8 to 10 percent, they were weighed on a triple-beam scale to the nearest 0.01 gram. Whenever possible, wedges of heartwood, sapwood, and mixed heartwood and sapwood (heart-sapwood) were obtained for each species. Each wedge, given an identification number, was stenciled as to species and classification. Classification indicated whether the wedge was heartwood, sapwood, or heart-sapwood.

The common and scientific names (6), source, specific gravity, number of wedges, and an indication as to classification for the 40 wood species represented in this test are presented in table 1. J. L. Stearns, wood anatomist, of Jenkintown, Pa., examined and verified the identity and representativeness of all 40 wood species included in this study.

For the first seven species there was a full complement of 200 wedges of heartwood, sapwood, and heart-sapwood. A single wedge of each classification was assigned to each of the 200 test plots. For species 8 to 23, the number of wedges ranged from 25 to 550, and they were not always classified. The wedges were distributed uniformly over the 200 plots so that an equal number would be exposed to *Poria* and to *Merulius*. The limited number of wedges of the tropical species were distributed at random.

After randomization, the wedges that were to be placed in any one plot were strung on a circle of wire in a definite recorded order (see Fig. 1). Wedges were placed in the plots on August 4, 1953.

A fourth of the wedges were removed at 6-month intervals. Twenty-five plots of *Merulius* and 25 plots of *Poria* were "harvested" at each interval. They were randomly selected so that six or seven plots of each block were included in each harvest. Immediately after removal from the plots, the wedges were air-dried to a moisture content of 8 to 10 percent as determined by a resistance-type moisture meter. They were then weighed and the weight-less percentage was calculated for each wedge.

Weight Loss Related to Exposure Time

The experiment demonstrated that the method of growing these test fungi under outdoor conditions used was both satisfactory and inexpensive. A vigorous fungus condition was maintained throughout the 2-year period, as evidenced by continuing deterioration of the test woods. Weight losses for the seven species grown in the United States exposed in all 200 plots are shown in Fig. 2. The average weight losses for these species for the four 6-month exposure intervals were 8.5, 13.3, 22.8, and 28.6 percent, respecticely.

Comparison of Weight Losses for Test Fungi

In every comparison between *Poria* and *Marulius* shown graphically in Fig. 2, the percentage weight loss was greatest for the wedges exposed to *Merulius*. The average differences between the fungi for all classes of wood were 1.1, 1.4, 4.1, and 4.6 percent, respectively, for the four exposure periods. The figure shows an increase in weight loss for each successive exposure period for each class of wood and fungus. The constancy of this increase precludes any interaction between exposure period and fungus species and between exposure period and class of wood.

United States Species: Fig. 3 presents the average weight loss of the first seven species listed in Table 1. The over-all weight loss for heartwood, heart-sapwood, and sapwood was 13.3, 18.3 and 24.4 percent, respectively. The species are arranged in the order of increasing weight loss from left to right. A fairly continuous increase over that of the previous period will be noted.

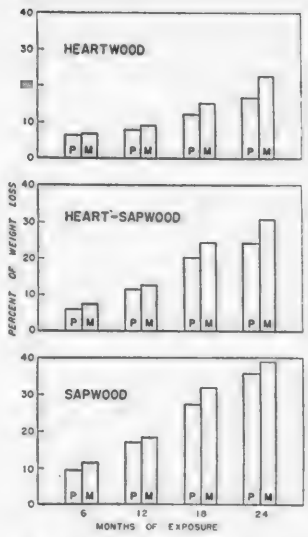

Fig. 2.—Comparison of weight-loss data for *Poria incrassata* (P) and *Merulius lacrymans* (M). Each bar represents an average of 175 wedges, 25 each of the first seven wood species listed in Table 1.

Fig. 4 presents the results obtained for species 8 to 23 of Table 1. Since the number of wedges included per fungus per species lacked orthogonality, and because of the relatively small numbers in some populations, these results are not considered to be so reliable as those for the first seven species. The species again are arranged in order of increasing weight loss; they show a comparison of the over-all difference between the two fungi.

The most striking features of the data for each of the 23 species grown in the United States are listed below.

Eastern redcedar.—The over-all weight loss for this species was 10.3 percent, which was smaller than for any other U.S. species shown in Fig. 3. Sapwood showed 5.0 times and heart-sapwood showed 2.7 times as much weight loss as did heartwood. There was no difference between the weight losses due to *Poria* and *Merulius*.

Atlantic white-cedar.—Over-all weight loss was 12.2 percent. Weight loss was considerably less during the first year of exposure than during the second.

Redwood.—Over-all weight loss was 15.7 percent. Heartwood showed less weight loss than sapwood, and was nearly comparable to hearwood of eastern redcedar. There was little difference between the averages for the two fungi in percent weight loss.

Northern catalpa.—Over-all weight loss was 16.5 percent. Weight losses were nearly identical for the two fungi. During the first 6 months, catalpa lost 13.6 percent of its weight, nearly three times as much as any of the three species discussed above.

Western redcedar.—Over-all weight loss was 16.7 percent. Largest increase in average weight loss occurred between the 12-month exposure (8.9 percent) and the 18-month exposure (24.0 percent). *Poria* caused an average 2 percent more weight loss than *Merulius.*

Baldcypress.—Over-all weight loss was 19.1 percent. Average weight losses were 12.5 percent for heartwood, 17.0 for heart-sapwood, and 27.7 for sapwood. There was 4.4 percent more weight loss due to *Merulius* than to *Poria.* Largest increase in weight loss was from 12.2 percent for 12 months to 26.6 for 18 months.

Eastern hemlock.—With 37.9 percent over-all weight loss, this species had by far the highest weight loss of any of the first seven species in Table 1. There was little difference among classes of wood. *Poria* averaged 33.3 percent, *Merulius,* 42.5 percent. Over-all weight loss at 24 months was 52.8 percent; the increase was approximately 10 percent every 6 months.

Osage-orange.—With an average weight loss of 2.2 percent for 125 wedges, Osage-orange showed the least weight loss of the 16 woods included in Fig. 4. It compares favorably with heartwood of eastern redcedar and redwood (Fig. 3). The difference in weight losses by fungi was not appreciable, and there was no apparent increase in loss with increasing exposure time.

Japanese chestnut.—Over-all weight loss was 2.8 percent. This species showed the least weight loss of the three chestnuts tested. The weight loss was three times as great for *Merulius* as for *Poria.* Many wedges actually gained a slight amount of weight in the first two sampling periods, and are included as negative values in the averages.

American smoketree.—Over-all weight loss for the 25 wedges was 7.5 percent. The difference in weight loss caused by the two fungi was not appreciable, and there was no consistent increase in weight loss with increase in exposure time.

White oak.—Over-all weight loss was 8.6 percent; 4.4 percent for *Poria,* and 12.8 for *Merulius.* Loss in weight for sapwood was nearly twice that for heartwood or heart-sapwood.

Black walnut.—Over-all weight loss was 9.6 percent. *Poria* resulted in 5.8 percent and *Merulius* 13.3 percent weight loss. There was little difference among classes of wood. There was an increase in weight loss at each sampling period, with a doubling of weight loss between the 18- and 24-month samplings.

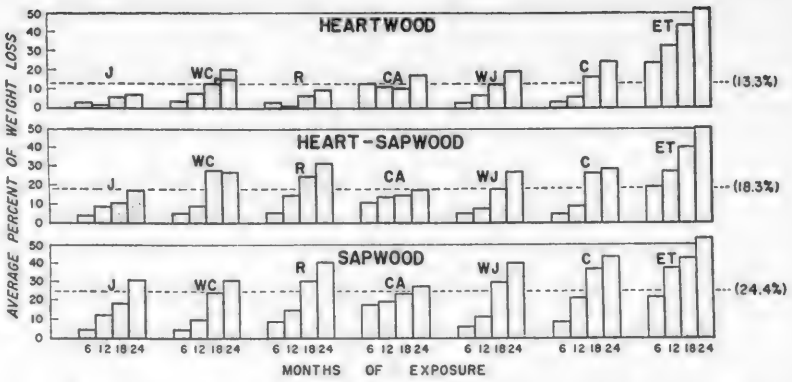

Fig. 3.—Percentage of weight losses of 7 wood species exposed for various periods to the 2 fungi. Each bar represents an average of 50 samples. The broken horizontal lines indicate over-all averages for the three classes of wood. J = eastern redcedar; WC = Atlantic white-cedar; R = redwood; CA = northern catalpa; WJ = western redcedar; C = baldcypress; ET = eastern hemlock.

Black locust.—Over-all weight loss was 11.9 percent, with no decided difference among classes of wood. Weight loss was less than 10.1 percent during the first 18 months, but by 24 months percent weight loss jumped to 17.7 for *Poria* and 27.5 for *Merulius.* Although the over-all weight loss for black locust was greater for *Poria* (Fig. 4), this relationship is true only during the first three sampling periods and may be due to the degree of infection in the particular plots sampled during the first three periods.

American chestnut.—Over-all weight loss was 13.8 percent. Weight loss increased to an average of 24.5 percent in the last sampling period.

Chinese chestnut.—Over-all weight loss of 14.9 percent was similar to that for American chestnut. *Poria* averaged 14.6 percent and *Merulius* 15.2 percent weight loss. Sapwood averaged 16.9 percent, compared with 13.0 percent for heartwood. There was only 3.6 percent more weight loss after 24 months than at 6 months.

Mesquite.—Over-all weight loss of the 25 wedges was 15.3 percent. *Merulius* resulted in a 4 percent greater weight loss than did *Poria.*

White mulberry.—Over-all weight loss was 16.0 percent. *Merulius* resulted in 3 percent more weight loss than did *Poria.* The 6-month average of 9.3 increased to 25.3 percent at the end of the 24-month exposure.

Longleaf pine.—This species, with an over-all average weight loss of 16.1 percent, was similar to white mulberry. *Merulius* caused nearly 6 percent more weight loss than did *Poria.* Heartwood (1.07 specific gravity), the heaviest of the U. S. grown species, had an over-all weight loss of 3.4 percent as compared to 20.0 for heart-sapwood and 23.9 for sapwood.

Northern white-cedar.—Over-all weight loss was 17.4 percent. *Poria* averaged 16.2 and *Merulius* 18.7 percent weight loss. Heartwood showed

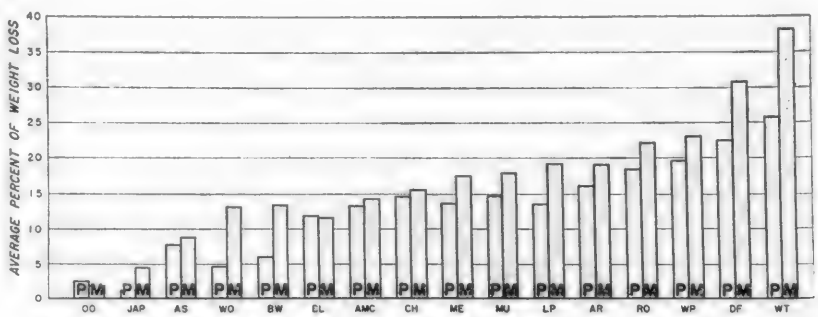

Fig. 4.—Over-all weight losses of 16 U.S.-grown woods exposed to *Poria incrassata* (P) and *Merulius lacrymans* (M). The number of wedges (per species) ranged from 12 to 275 per bar. OO = Osage-orange; JAP = Japanese chestnut; AS = American smoketree; WO = white oak; BW = black walnut; BL = black locust; AMC = American chestnut; CH = Chinese chestnut; ME = mesquite; MU = white mulberry; LP = longleaf pine; AR = northern white-cedar; RO = northern red oak; WP = eastern white pine; DF = Douglas-fir; WT = western hemlock.

only 8.3 percent weight loss, in contrast to 16.4 for heart-sapwood and 27.5 for sapwood.

Northern red oak.—Over-all weight loss was 20.6 percent, with *Poria* resulting in 5.0 percent less weight loss than *Merulius.*

Eastern white pine.—Over-all weight loss was: 20.8 percent. *Merulius* caused an average 3 percent more loss than did *Poria.* For 6 months there was only 3.4 percent weight loss, but by 24 months this loss had increased to 37.6 percent. Sapwood wedges exposed to *Merulius* for 24 months averaged 55.0 percent weight loss. Heartwood lost only half as much weight as did sapwood.

Douglas-fir.—Over-all weight loss was 26.7 percent, 22.3 for *Poria* and 31.5 for *Merulius.* There was an increase in weight loss by steps from 9.0 to 44.9 percent with lengthening exposure time.

Western hemlock. — This species, with an average over-all weight loss of 31.7 percent, was exceeded only by eastern hemlock. *Merulius* caused 37.2 percent weight loss, 11 percent greater than *Poria.* Class of wood did not influence amount of loss for either fungus, and there was a step-wise increase with increasing exposure time. The average for all wedges exposed for 24 months was 42.9 percent, but was 58.2 percent for those exposed to *Merulius.*

Tropical species: Average weight loss for the four wedges of the 17 tropical hardwoods species are presented in the last column of Table 1. The small number of wedges used for each species and the lack of orthogonality in regard to fungus species and sampling periods make these means much less reliable than the means for the species grown in this country. Averages for the species ranged from —0.3 to 24.6 percent weight loss. None of the Brazilian rosewood wedges actually lost weight, and three wedges exposed to *Merulius* actually gained weight. In this study, African mahogany and Ohia were the least durable species. Eight of the 17 tropical species had less weight loss than any of the U. S. species. An inspection of the specific gravities given in Table 1 shows that the tropical species were generally heavier than those grown in the United States.

Discussion of Results

The over-all data show that *Merulius* resulted in decidedly more weight loss than did *Poria.* To the authors' knowledge this had never been reported before. Other researchers have demonstrated that *Poria* can seriously attack woods usually considered to have high decay resistance. These data show that *Merulius* also has this ability. There appears to be some interaction between wood and fungus species, however, since of the 23 woods grown in this country, seven show a difference between the fungus species of less than 1 percent, six show a difference of more than 5 percent, and western hemlock showed 11 percent more weight loss when exposed to *Merulius.*

Heretofore, the European *Merulius lacrymans* was thought to have limited distribution in America because its optimum temperature range, under laboratory conditions, is 18° to 20° C. in contrast to 24° to 30° C. for *Poria incrassata* (3). The establishment of these plots, in addition to 120 similar plots in 10 Southern and Midwestern States, demonstrates that temperature is not a limiting factor.

Although J. L. Stearns examined the samples of wood used in the test for their representativeness and verified that they were the species claimed, the authors realize that the one or two samples of wood selected do not represent all variations that may occur in a species. Therefore the data are given in Table 1 to help characterize the samples to the best of the authors' knowledge. Although weight loss is commonly used as a measure of decay resistance, the authors feel that weight loss caused by the two fungi, both of which are of the brown-rot type, may not be adequate in setting up decay-resistance ratings.

Of the U. S.-grown species exposed in 200 plots, none was found to be completely free from weight loss. In all but eastern hemlock, considerably less weight loss was shown by the heartwood. For eastern hemlock the weight loss for heartwood at 6 months was greater than the weight loss for the heartwood of any other species after as much as 24 months of exposure. Heartwood of eastern redcedar and redwood showed less than than 10 percent weight loss at all exposure periods. Atlantic white-cedar, western redcedar, and baldcrypress heartwood showed less than 10 percent weight loss the first year, but showed more weight loss in the second year. As expected, the weight loss for the heart-sapwood was intermediate between those for heartwood and for sapwood (Fig. 3). Catalpa showed less weight loss variation with length of exposure than any other species.

Baldcrypress, which is reputed to be quite durable, made a rather poor showing in this test. The weight loss, although not excessive for the first 6 months, increased step-wise with each exposure period. The cypress used in this test was from Texas. Mattoon (7) reported large tree-to-tree variation in natural durability for baldcrypress. He pointed out that in fence lines some crypress posts must be replaced sooner than others, that in boats some planks decay while others last for extended periods, and that in old cuttings the flat tops of large stumps vary in soundness although the trees were the same age. Verrall (9) states that *Poria incrassata* sometimes enters buildings through wooden piers of baldcrypress heartwood.

Of the U. S.-grown species exposed in less than 200 plots, Osage-orange, Japanese chestnut and American smoketree were found to lose less weight than the other species. Verrall (9) cites a case in Texas where Osage-orange piers remained unaffected in a house attacked by *Poria incrassata.* One of the earliest and most extensive outdoor relative durability ratings of untreated posts in service was made by Crumley (2). Over a period of years he took notes on 30,160 posts in 292 fences located in Ohio, Indiana, Illinois, Kansas, and Texas. He found Osage-orange to be the most durable, with no close competitors.

Although white oak and black walnut showed little weight loss when exposed to *Poria,* they both showed considerably weight loss when exposed to *Merulius.* Mesquite, white mulberry, and longleaf pine all showed moderate weight loss. Douglas-fir and western hemlock showed the largest weight losses of the species in Fig. 4.

With several exceptions, the weight-loss ratings of 20 U. S.-grown woods in the present study agree favorably with those of previous published durability ratings (8, 4, 10) based primarily on field service records.

Although redwood is rated as the third most durable species, forest pathologists (5) have recently reported two types of decay-producing fungi that result in extensive cull in heartwood of living redwoods in California.

A close inspection of Table 1 will reveal that there is very little relationship between specific gravity and weight loss for heartwood of the various species. Among the U. S.-grown species exposed in 200 plots, the greatest and least weight losses were observed for the two species with the highest average specific gravities for heartwood. The average correlation between specific gravity and weight loss within test fungi and exposure period for heartwood of longleaf pine was calculated to be 0.08, which is not significant with 44 degrees of freedom. It is concluded, therefore, that variation in specific gravity within this species is not a factor in percent weight loss. Also, there seems to be no relationship between a classification into

Table 1.—DATA ON THE 40 WOOD SPECIES INCLUDED IN STUDY

Scientific name[1]	Common name	Source	Specific gravity[2]	Number of wedges	Classified[3]	Weight loss,[4] percent
U. S.-Grown Species Exposed in 200 Plots						
1. *Catalpa speciosa* Warder	Northern catalpa	Ohio	0.46	600	Yes	17.1
2. *Chamaecyparis thyoides* (L.) B. S. P.	Atlantic white-cedar	N. Carolina	.41	600	Yes	13.4
3. *Juniperus virginiana* L.	Eastern redcedar	Ala. Mo. Tenn.	.54	600	Yes	5.7
4. *Sequoia sempervirens* (D. Don) Endl.	Redwood	Open market	.50	600	Yes	8.2
5. *Taxodium distichum* (L.) Rich.	Baldcypress	Texas	.43	600	Yes	24.3
6. *Thuja plicata* Donn	Western redcedar	Idaho	.43	600	Yes	20.2
7. *Tsuga canadensis* (L.) Carr.	Eastern hemlock	Pennsylvania	.58	600	Yes	53.3
U. S.-Grown Species in Less Than 200 Plots						
8. *Castanea crenata* Sieb. & Zucc.	Japanese chestnut	Pa., Va.	0.76	100	No	6.9
9. *Castanea dentata* (Marsh.) Borkh.	American chestnut	Virginia	.72	75	No	24.5
10. *Castanea mollissima* Blume	Chinese chestnut	Maryland	.77	300	Yes	14.5
11. *Cotinus obovatus* Raf.	American smoketree	Alabama	.62	25	No	8.8
12. *Juglans nigra* L.	Black walnut	Stearns[5]	.78	150	Yes	16.3
13. *Maclura pomifera* (Raf.) Schneid.	Osage-orange	Mo., Texas	.79	125	No	3.0
14. *Morus alba* L.	White mulberry	Virginia	.77	75	No	25.4
15. *Pinus palustris* Mill.	Longleaf pine	Texas	1.07	175	Yes	8.4
16. *Pinus strobus* L.	Eastern white pine	Maine	.58	150	Yes	23.0
17. *Prosopis juliflora* (Sw.) DC	Mesquite	Texas	.78	25	No	28.7
18. *Pseudotsuga menziesii* (Mirb.) Franco	Douglas-fir	Open market	.53	225	No	44.9
19. *Quercus alba* L.	White oak	Stearns[5]	.80	150	Yes	13.0
20. *Quercus rubra* L.	Northern red oak	W. Virginia	.68	220	No	30.8
21. *Robinia pseudoacacia* L.	Black locust	Md., N. Y.	.80	150	Yes	23.5
22. *Thuja occidentalis* L.	Northern white-cedar	Open market	.40	450	Yes	13.6
23. *Tsuga heterophylla* (Raf.) Sarg.	Western hemlock	Oregon	.49	550	Yes	51.1
Tropical Species[5]						
24. *Bombacopsis quinatum* (Jacq.) Dugand	Pochote	Costa Rica	0.59	4	No	0.5
25. *Cedrela mexicana* Roem.	Spanish cedar	Mexico	.45	4	No	16.0
26. *Chlorophora excelsa* Benth. & Hook. f.	Iroka	W. Africa	.49	4	No	17.0
27. *Copaifera demeusei* Harms	Bubinga	W. Africa	.95	4	No	7.1
28. *Dalbergia latifolia* Roxb.	E. Indian Rosewood	E. Indies	.76	4	No	.4
29. *Dalbergia nigra* Fr. Allem.	Brazilian Rosewood	Brazil	.96	4	No	—.3
30. *Guaiacum sanctum* L.	Lignumvitae	Florida	1.33	4	No	—.1
31. *Khaya ivorensis* A. Chev.	African mahogany	W. Africa	.52	4	No	24.6
32. *Meterosideros polymorpha* Gaud.	Ohia (Ohia Lahu)	Hawaii	.89	4	No	20.5
33. *Mimusops salzmanii* A. DC.	Massaranduba	Brazil	1.19	4	No	.6
34. *Ocotea rodiaei* (R. Schomb.) Mez	Greenheart	Brit. Guiana	1.14	4	No	12.9
35. *Piratinera guianensis* Aubl.	Snakewood	Brit. Guiana	1.43	4	No	3.3
36. *Pterocarpus soyauxii* Taub.	Paduak, African	W. Africa	.70	4	No	1.7
37. *Schinopsis balansae* Engler.	Quebracho	Argentina	1.31	4	No	.8
38. *Shorea negrosensis* Foxw.	Lauan, Red	Philippines	.53	4	No	15.2
39. *Swietenia macrophylla* King	Mahogany	Honduras	.59	4	No	2.4
40. *Tectona grandis* L. f.	Teak	Burma	.65	4	No	1.5

[1] Names of U. S. species in accordance with U. S. Forest Service usage; names of tropical species in accordance with most prevalent international usage.
[2] Determination made on a limited number of heartwood wedges by water displacement. For the average specific gravities of wood species see Wood Handbook (8).
[3] "Yes" indicates classification of wedges into heartwood, heart-sapwood or sapwood; "No" indicates disregard of type of wood.
[4] Values given are averages for heartwood only at the 24-month period for species that were classified. For other U. S. species the values are over-all averages for the 24-month period. For tropical species the values are the averages for all four wedges. A negative value indicates that the wedges actually gained weight.
[5] Samples provided by J. L. Stearns, 1112 Beverly Road, Jenkintown, Pa.

coniferous and broadleaved species and weight-loss ratings.

Worthwhile problems for further research work are: 1) the reason for the apparent resistance of certain wood species to these fungi, and 2) reasons why certain wood species are attacked by one of the two fungi more than the other.

This study suggests that some tropical species are resistant to the attack of *Poria* and *Merulius*, but further testing would be needed to confirm this.

Summary

The fungi *Poria incrassata* (Berk. & Curt.) Burt. and *Merulius lacrymans* Fr. were grown successfully for a 2-year period under mounds of forest leaves in a wooded area at Beltsville, Md. The only maintenance required on the test plots was an occasional watering during the hottest, driest periods.

Comparison of weight-loss data for the two fungi during a 2-year period demonstrated that *Merulius* caused more weight loss than *Poria*. There appears to be some interaction between wood species and the two fungi, however.

All of the 23 U. S.-grown wood species showed some weight loss by the end of the 2-year period. For the seven wood species for which 200 wedges each of heartwood, heartsapwood, and sapwood were tested, heartwood showed considerably less weight loss than the other two classes, with the exception of eastern hemlock. Heartwood of this species had as much weight loss as did the sapwood. The two species that showed the least weight loss were the heartwoods of eastern redcedar and redwood, both with less than 10 percent loss during all exposure periods. Atlantic white-cedar, western redcedar, and baldcypress heartwoods showed less than 10-percent weight loss the first year, but showed considerably greater weight loss in the second year.

Of the 16 U. S.-grown species exposed in less than 200 plots, those with the least weight loss were Osage-orange, Japanese chestnut, and American smoketree. White oak and black walnut were found to have less weight loss when exposed to *Poria* than to *Merulius*. Douglas-fir and western hemlock had the most weight loss of the 16 species.

In the limited study of the 17 tropical woods, five species showed less than 2 percent weight loss. The two species that showed most weight loss were African mahogany and Ohia.

Weight loss was not related to specific gravity. Broadleaved species showed as much weight loss as coniferous species.

Literature Cited

1. Cartwright, K. St. G., and W. P. K. Findlay. 1950. Decay of timber and its prevention. Dept. Sci. and Indus. Res. 294 pp., illus. London.
2. Crumley, J. J. 1910. The relative durability of post timbers. Ohio Agr. Expt. Sta. Bul. 219.
3. Davidson, R. W. and F. F. Lombard. 1953. Large brown-spored house-rot fungi in the United States. Mycologia 45: 88.
4. Hunt, G. M. 1941. Factors that influence the decay of untreated wood in service and comparative decay resistance of different species. U.S. Forest Prod. Lab. Rpt. R68.
5. Kimmey, J. W., and P. C. Lightle. 1955. Fungi associated with cull in redwood. Forest Sci. 1: 104.
6. Little, E. L., Jr. 1953. Check list of native and naturalized trees of the United States. U.S. Dept. of Agr. Handbook 41, 472 pp.
7. Mattoon, W. R. 1915. The southern cypress. U.S. Dept. Agr. Tech. Bul. 272, 74 pp.
8. United States Forest Products Laboratory. 1955. Decay resistance of heartwood of native species. *In* Wood Handbook. U.S. Dept. Agr. Handbook 72. 528 pp., illus.
9. Verrall, A. F. 1954. Preventing and controlling water-conducting rot in buildings. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 133, 14 pp.
10. White, D. O. 1922. Relative durability of untreated native woods. South. Lumberman 107 (1406): 46.

LIGNUM-VITAE logs being prepared in Nicaragua, for shipment to U. S.

—photos courtesy Lignum-Vitae Products Corp., Jersey City, N. J.

SELECTIVE CUTTING of choice portion of log for use in marine propeller shaft bearings.

AN INVESTIGATION OF CERTAIN PHYSICAL AND MECHANICAL

Properties of Lignum-vitae[1]

SHELDON GREENE

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A study of the "tree of life" to evaluate certain properties that would be helpful in the use of Lignum-vitae under various industrial and mechanical service conditions.

THE WOOD COMMONLY CALLED Lignum–vitae has been a material of commercial importance since 1508, when it was first introduced to the medical profession of Europe as a panacea for some of the most serious diseases. Although this wood is no longer seriously considered as a "cure all" medicine, the gum extractive of Lignum–vitae is still included in some medicinal preparations for its balsamic qualities. However, the name Lignum–vitae (tree of life) remains as a testimonial to its early use (2).[2] Today, Lignum–vitae is utilized mechanically for its extreme hardness, durability, and self-lubricating qualities.

Commercial quantities of Lignum-vitae are chiefly obtained from two species of the genus *Guaiacum; G. officinale* L. and *G. guatemalense* Plancli. These species are found on the West Coast of Central America, Cuba, Jamaica, Haiti, and the Dominican Republic (2).

The principal uses of Lignum–vitae are for self-lubricating bearings or bushing blocks lining the stern tubes of propeller shafts of ships and submarines, pulleys, rollers, slides and guides, mallets, and for bearings, bushings, and pillow blocks in industrial applications (5). It is even being used as motor mounts in large trailer trucks. Due to its non-contaminating quality, it is also used for utensils in the food-handling field.

In this study the following physical and mechanical properties were investigated. 1. Shear paralled to the grain 2. Hardness 3. Toughness 4. Chemical resistance 5. Effect of boiling water on abrasion resistance 6. Bearing characteristics at sub-zero temperatures and 7. Coefficient of friction.

The Author: Sheldon Greene is a graduate of Yale's School of Forestry and holds a masters degree in forestry and wood technology. He received his B.S. degree in forestry from the U. of Massachusetts. He was a staff member of Timber Engineering Co., Washington, D. C., while preparing this paper. He is currently with Hammond Organ Co., Chicago, Ill.

Material Tested

The Lignum–vitae selected for testing was clear heartwood. The average air-dry moisture content, as determined by the distillation method, was 9.25 percent and ranged from 5.84 to 11.77 percent. The specific gravity (oven-dry weight–air-dry volume) averaged 1.21, with a range of 1.17 to 1.26.

Physical and Mechanical Tests

Shear Parallel to the Grain: Ten specimens were tested for shear strength parallel to the grain according to A.S.T.M. Designation 143–52 "Tests for Small Clear Timber Specimens." Five of the specimens were machined so that the shearing stress was applied radially; the remaining five specimens were cut so that the stress was applied tangentially.

The shear strength of the Lignum–vitae tested is shown in Table 1. The average shear strength in the radial plane was 1977 psi, while in the tangential plane it was 1701 psi. The average shear strength of the ten specimens tested was 1839 psi. For comparison, the shear strength of sugar maple and yellow birch, taken from published literature, are also listed in Table 1 (1).

[1] A contributed paper sponsored by the Lignum–Vitae Products Corporation, Jersey City, N. J. (November, 1958).

[2] Numbers in parentheses refer to the literature cited at the end of this paper.

Table 1.—RESULTS OF SHEAR TESTS PARALLEL TO THE GRAIN CONDUCTED ON LIGNUM-VITAE SAMPLES. TESTS WERE CONDUCTED ON A BALDWIN-SOUTHWARK UNIVERSAL TESTING MACHINE

	Shear Strength	
	Radial surface PSI	Tangential surface PSI
Average (5 specimens)	1977	1701
Range	1620–2270	1470–1860
Combined average	1839	
Sugar Maple	2330[1]	
Yellow birch	1880[1]	

[1]Forest Products Laboratory, Wood Handbook, USDA Handbook No. 72, Washington, D. C. 1955 page 83.

Hardness: A modified hardness test was used to determine the hardness modulus of Lignum–vitae (4). The standard A.S.T.M. hardness test was not applicable, since the extreme density of the Lignum–vitae causes a bulging of the wood which prevents full penetration of the hemispherical tip of the hardness tool. In addition to the latter difficulty, splitting of the specimens also occurred during the standard hardness test.

The modified hardness test differs from the standard hardness test in that complete penetration of the hemispherical tip of the hardness tool in the material under test is not required. Instead, the collar of the hardness tool is removed, and a micrometer dial, reading in 0.001-inch, is fastened to the shaft of the tool. Penetration of the hemispherical tip of the tool is recorded at convenient load increments until a sufficient number of readings have been made to enable a straight line to be fitted through the plotted load-penetration points.

The hardness modulus is calculated from the relationship:

$$Hm = P/2\pi rh = 0.717\ P/h$$

where:

Hm = load per unit of spherical area of penetration, psi.
P = load, pounds
h = penetration, inches at P

Using this method, five specimens of Lignum-vitae, each 2″ x 2″ x 6″, were tested. Two penetrations were made on the tangential surface, two on the radial surface, and two on each end. Penetration was at a rate of 0.2-inch per minute.

Table 2 presents the hardness modulii for the Lignum-vitae tested. The average hardness modulus on the radial face was 22,180 psi; on the tangential face, 19,770 psi; and on the ends, 16,450 psi. The reduced end hardness appears to be typical of very dense woods. The combined average for the tangential and radial faces was 20,975 psi. For comparison with the hardness modulii of Lignum-vitae, Table 3 lists the hardness modulii of various species of woods, as indicated in published literature (4).

Table 3.—HARDNESS MODULI OF VARIOUS SPECIES OF WOODS[1]

Species	Specific gravity[2]	Hardness modulus PSI
Balsa	0.13	290
Basswood	.44	1,960
Birch, yellow	.61	3,770
Cottonwood	.50	3,370
Douglas fir	.60	2,580
Elm, rock	.53	2,380
Maple, sugar	.70	5,520
Pine, eastern white	.39	1,490
Poplar, yellow	.45	1,620
Sitka spruce	.38	1,430
Teak	.62	3,020

[1]Weatherwax, R. C., E. C. O. Erickson, and A. L. Stamm, A Means of Determining the Hardness of Wood and Modified Woods Over a Broad Specific Gravity Range. ASTM Bulletin No. 153 pp. 84–89. August 1948.
[2]Based on oven-dry weight and volume at test.

Toughness: The toughness values for 20 specimens of Lignum-vitae were determined on a Forest Products Laboratory-type toughness testing machine in accordance with A.S.T.M. Designation 143–52, "Tests for Small Clear Timber Specimens." Ten specimens were loaded on the radial face and ten on the tangential face. The toughness values of each specimen, in inch-pounds, were obtained from published calculated values entitled "Calculated Toughness Values for Use with Forest Products Laboratory Toughness-Testing Machine" (3).

The toughness values for the Lignum-vitae specimens tested are given in Table 4. Values of sugar maple and yellow birch, taken from published data, are also included in this table (1).

Table 4.—RESULTS OF TOUGHNESS TESTS CONDUCTED ON LIGNUM-VITAE SPECIMENS TESTED IN A FOREST PRODUCTS LABORATORY-TYPE TOUGHNESS TESTING MACHINE.

	Toughness Values	
	Radial Inch-pounds	Tangential Inch-pounds
Average (10 specimens)	135.0	195.5
Range	56.4–194.0	82.4–295.2
Combined average	165.5	
Yellow birch	260.0[1]	330.0[1]
Sugar maple	190.0[1]	190.0[1]

[1]Forest Products Laboratory Wood Handbook, USDA Handbook No. 72, Washington 25, D. C., 1955.

Table 2.—RESULTS OF MODIFIED HARDNESS TESTS CONDUCTED ON LIGNUM-VITAE SPECIMENS

	Hardness modulus		
	Tangential surface PSI	Radial surface PSI	End surface PSI
Average	19,700[1]	22,180[1]	16,450[2]
Range	16,700–22,400	15,900–26,600	11,950–19,400
Average of tangential and radial	20,957		

[1]Average of 10 tests. [2]Average of 20 tests.

The average toughness value for the Lignum-vitate specimens loaded on the radial face was 135.0 inch-pounds, while the average value for those loaded on the tangential face was 195.5 inch-pounds. The combined average was 165.5 inch-pounds.

Chemical Resistance: Because Lignum-vitate is used in situations where it is exposed to various reagents, it was felt that an important phase of this study would be an evaluation of the effect of a number of reagents on the wood. It is known that Lignum-vitae has unusual resistance to many acids and harsh chemicals, in comparison to various other industrial materials, but a quantitative measure of this resistance was desired.

This was accomplished by determining the changes occurring in weight, dimension, and abrasion resistance after seven days' immersion at room temperature in the following reagents: a) Sulphuric acid (3%), b) Sulphuric acid (30%), c) Sodium hydroxide (1%), d) Sodium hydroxide (10%), e) Ethyl alcohol (50%), f) Ethyl alcohol (95%), g) Sodium Chloride (10%), h) Ethyl acetate, i) Carbon tetrachloride, j) Toluene, k) Heptane, l) Acetone, m) Acetic acid (5%).

Three specimens, each measuring ½″ x 4″ x 4″, and having a ¼″ hole at the center, were immersed in each reagent. Prior to immersion, each specimen was weighed to the nearest 0.05 gram and its three dimensions measured to an accuracy of 0.001 inch.

Each reagent was contained in a clean porcelain pan and the three specimens in each reagent separated by wooden stickers so as to expose all surfaces to the action of the reagent. The pans were covered during the seven days' immersion to prevent evaporation. Each reagent was stirred daily to minimize stratification.

On completion of the 7-day immersion period, each specimen was wiped clean and re-weighed and measured. The weight and dimensional change was calculated as a percent of the original air-dry weight and dimension.

The abrasion test was performed on a Taber abraser as shown in Fig. 1. The two abrasive coated wheels were held in contact with the specimen surface by a pressure of 1000 grams exerted on each wheel. No. 40 Garnet Cloth was used as the abrasive for the testing of the Lignum-vitae and fresh abrasive was used for the individual tests. Each specimen was subjected to 500 cycles on the Taber abraser for determination of abrasion resistance.

Although other methods of evaluating abrasion resistance are known the Taber abraser was used because it provided good control of the several

variables of abrading material, applied abrasion load on the specimen, and duration of test.

The amount of abrasion occurring was measured with a depth gage to an accuracy of 0.0005 inch. The standard weight-loss method for determining abrasion resistance could not be employed due to the loss and gain of moisture during weighing and the small amount of wood abraded. Three untreated, air-dry specimens and three water-soaked specimens were tested as controls. In addition, three air-dry end-grain specimens were also tested.

An "Index of Abrasion Resistance" was calculated from the following relationship:

$$R = De/Dt \times 100$$

where:

R = abrasion resistance index
Dc = depth of abrasion of controls
Dt = depth of abrasion of treated specimens

In this system of classification, a resulting high index number indicates less reagent effect on specimen abrasion resistance than lower ones. The depths of abrasion of the three treated specimens in each set were averaged and this value used in computing the index. The index was computed using both the untreated, air-dry specimens and the water-soaked specimens as controls.

The results of the chemical resistance tests are given in Table 5. The reagents are listed in decreasing order of effect on abrasion resistance.

The 10 percent sodium hydroxide has the most adverse effect on the Lignum-vitae, causing the greatest amount of weight change, dimensional change, and decrease in abrasion resistance. This is possibly due to the fact that the highly alkaline solution readily dissolves the oily, water-resistant material in the wood, allowing moisture to enter the wood structure and cause swelling and weight increase. The abrasion resistance is adversely affected because of the loss of oily material from the wood and the softening of the wood tissue resulting from the action of the strong alkali and from an increase in moisture content.

The 1 percent sodium hydroxide, 3 percent sulphuric acid, and 5 percent acetic acid, because of their low concentrations, have nearly the same effect on weight and dimensional changes as water alone. The slight decrease in length noted with the 3 percent sulphuric acid and the 5 percent acetic acid may be due to the dissolving of a thin layer of the oily material on the end grain surfaces of the wood. These reagents cause a moderate decrease in abrasion resistance.

Fig. 1.—The Taber abraser used to test the effect of various treatments on the abrasion resistance of Lignum-vitae.

The 30 percent sulphuric acid has a slight negative effect on the dimensions of the Lignum-vitae, presumably caused by the hydrolyzing and desiccating action of the acid. The weight change and abrasion resistance are affected very little.

The 25 percent ethyl alcohol has a desiccating effect on the Lignum-vitae, causing a loss of moisture and subsequent decrease in weight and dimensions. The 50 percent ethyl alcohol does not show this to so marked a degree, although the weight and dimensions decreased very slightly. The abrasion resistance is lowered somewhat by soaking in alcohol, although there does not seem to be a significant difference in the effects of the two concentrations used.

Carbon tetrachloride, toluene, heptane, and ethyl acetate have approximately equal effects on the weight and dimensional changes of Lignum-vitae. The decrease in both quantities is possibly caused by the dissolving of some of the oily material on the surfaces of the specimens. The toluene and heptane cause a much greater decrease in the abrasion resistance than do the carbon tetrachloride and ethyl acetate.

The 10 percent sodium chloride solution causes a moderate increase in weight and dimensions. The abrasion resistance, however, is lowered appreciably.

Effect of Boiling Water on Abrasion Resistance: Two sets of three specimens each were used to determine the effect of boiling water on the abrasion resistance of Lignum-vitae. The used in the study of chemical resistspecimens were of the same type as ance. One set of three specimens was soaked for one week in water, while the second set of three specimens was soaked for six days and then subjected to eight hours of boiling, followed by 16 additional hours of soaking. During the boiling operation the specimens were placed in fresh boiling water at 2-hour intervals.

Upon completion of the soaking and boiling phase, both sets of specimens were subjected to the same abrasion test as used in the chemical resistance study. The "Index of Abrasion Resistance" was calculated, based on both the untreated, air-dry controls and the water-soaked controls.

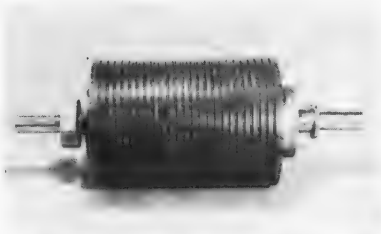
The results of the tests for the effect of boiling water on abrasion resistance are listed in Table 6.

Boiling water severely effects the abrasion resistance of Lignum-vitae, causing a loss in abrasion resistance of 37 percent, as compared with untreated, air-dry Lignum-vitae and 32 percent as compared with Lignum-vitae which has been soaked in water at room temperature for one week.

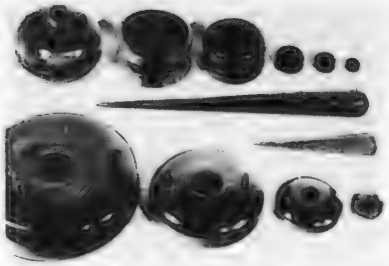
The decrease in abrasion resistance from boiling water is caused by the softening action of this treatment on the wood tissue. The high temperature to which the wood is exposed during boiling causes a much greater degree of softening than is caused by soaking at room temperature, although the latter does have a slight softening effect.

Bearing Characteristics at Sub-zero Temperatures:—Four specimens of Lignum-vitae, similar to those used in the chemical resistance tests, were immersed in water at room temperature for two weeks and then conditioned to sub-zero temperatures by storage between blocks of dry ice. After storage in this manner for 72 hours, the abrasion resistance of each specimen was determined, as previously described, in a chamber maintained at a temperature of approximately —5° F.

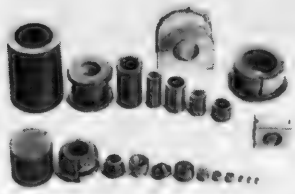
Although it was recognized that the friction of the Tabor abraser would cause an increase in specimen temperature, it was felt that any effect on abrasion resistance due to freezing would still be evaluated by this method. The maintenance of the chamber temperature at —5° F. prevented any substantial increase in specimen temperature from occurring. The abrasion resistance was calculated as an "Index of Abrasion Resistance" based on both the untreated, air-dry controls and the water-soaked controls.



MULTI-GROOVED lignum-vitae roller used in fabricating twine. The hard surface and natural resin smooths and burnishes the twine as it moves through the grooves.



MARINE AND AWNING equipment items; deadeye for guiding rope; fids, used for splicing rope; different sizes of mast trucks used on masts and flag poles for raising and lowering flags and sails.



ASSORTMENT of self-lubricating lignum vitae bearings, bushings, pulleys, rollers wheels and small spheres used by industry for many purposes.

The results of the abrasion tests conducted at sub-zero temperatures are shown in Table 7. The average abrasion resistance is similar to that of untreated, air-dry Lignum-vitae and somewhat higher than for water-soaked specimens.

Coefficient of Friction: The coefficients of static friction were determined for Lignum-vitae, Arguto (oil-impregnated maple), Nylon, and Micarta in contact with cold-rolled steel. The coefficients of kinetic friction, both dry and water-immersed, were determined for Lignum-vitae, Arguto, Nylon, Micarta, and Parock in contact with cold-rolled steel.

Three specimens each of Lignum-vitae and Arguto and two specimens each of the other materials were tested. The surfaces of all specimens were prepared for test in an identical manner so as to avoid surface variation as much as possible. Test specimens measured 7/8" x 2" x 2" in size. In addition, three Lignum-vitae and three Arguto specimens were prepared with the fibers of the wood parallel to the small dimension. These were tested to determine the end-grain coefficient of friction.

The coefficient of static friction was determined by placing a specimen on a cold-rolled steel plate and inclining the plate until the test specimen began t slide. In order to insure intimate con tact between the steel and the tes specimen, a small metal block wa placed on top of each specimen prio to inclination of the plate. The coeffi cient of static friction is equal to th tangent of the angle of inclination a the point where movement of th specimen begins.

To determine the coefficient of ki netic or sliding, friction, each specime was placed on the steel plate, whic was previously leveled so as to provid a horizontal plane. A normal, or ver tical, load was applied to the tes specimen and, while under this load

TABLE 5

Summary of results of chemical resistance tests conducted on Lignum-vitae specimens subjected to various reagents 1/

Reagent	Weight change	Length change	Width change	Thickness change	Abrasion	Index of Abrasion resistance	
						Air-dry = 100	Water-soaked = 100
	Per cent	Per cent	Per cent	Per cent	Inches		
Sodium hydroxide(10%)	+7.60	+0.09	+1.26	+4.46	0.0180	57	61
Toluene	-1.39	-0.06	-0.65	-0.40	0.0150	68	73
Sodium chloride (10%)	+2.29	-0.10	+0.92	+0.80	0.0147	69	75
Ethyl alcohol (50%)	+0.89	-0.02	-0.38	+1.00	0.0138	74	80
Heptane	-1.15	-0.04	-0.47	-0.30	0.0138	74	80
Sulphuric acid (3%)	+3.99	-0.09	+1.68	+1.59	0.0132	77	83
Sodium hydroxide (1%)	+3.89	+0.10	+1.52	+2.05	0.0132	77	83
Acetic acid (5%)	+3.14	-0.07	+1.46	+1.32	0.0132	77	83
Ethyl alcohol (95%)	-2.01	-0.01	-0.48	-0.27	0.0128	80	86
Ethyl acetate	-1.29	-0.03	-0.01	0.00	0.0115	89	96
Acetone	-3.35	-0.09	+0.33	+1.11	0.0115	89	96
Carbon tetrachloride	-1.54	-0.11	-0.47	-0.66	0.0133	90	97
Sulphuric acid (30%)	+0.72	-0.05	-0.27	-0.20	0.0110	93	100
Water	+5.30	+0.19	+2.36	+1.68	0.0110	93	100
Air-dry, untreated	- -	- -	- -	- -	0.0102	100	108
Air-dry, untreated end grain	- -	- -	- -	- -	0.0090	113	122

1/ Each value represents an average of 3 specimens tested.

Table 6.—RESULTS OF TESTS CONDUCTED ON LIGNUM-VITAE SPECIMENS TO DETERMINE THE EFFECT OF BOILING WATER ON ABRASION RESISTANCE

Treatment	Abrasion inches	Index of abrasion resistance: Air-dry = 100	Index of abrasion resistance: Water-soaked = 100
Boiled (soaked 6 days—boiled 8 hours)	0.0161	63	68
Water-soaked (7 days)	.0110	93	100
Air-dry, untreated	.0102	100	108

Table 7.—RESULTS OF TESTS CONDUCTED ON LIGNUM-VITAE SPECIMENS TO DETERMINE BEARING CHARACTERISTICS AT SUB-ZERO TEMPERATURE

Treatment	Abrasion inches	Index of abrasion resistance: Air-dry = 100	Index of abrasion resistance: Water-soaked = 100
Frozen and tested at sub-zero temperatures	0.0101	101	110
Air-dry, untreated	.0102	100	108
Water-soaked (7 days)	.0110	93	100

Table 8.—AVERAGE COEFFICIENTS OF STATIC AND KINETIC FRICTION FOR LIGNUM-VITAE AND FOUR OTHER MATERIALS TESTED IN CONTACT WITH A COLD ROLLED STEEL PLATE

Material	Direction of motion	Average coefficients of friction: Static	Kinetic or sliding: Dry	Kinetic or sliding: Water immersed
Lignum-vitae	Parallel to grain	0.37	0.158	0.253
Lignum-vitae	Perpendicular to grain	.33	.158	.192
Lignum-vitae	Parallel to cross section	.34	.160	.094
Arguto	Parallel to grain	.44	.123	.256
Arguto	Perpendicular to grain	.39	.123	.235
Arguto	Parallel to cross-section	.41	.125	.206
Micarta	Parallel to laminations	.31	.225	.318
Nylon		.36	.160	.141
Parock		----	.229	.193

the block was pulled along the steel plate by a spring scale (dynamometer) having a 10-pound capacity and capable of being read to the nearest 2 ounces. The motion of the test block was maintained at a velocity of approximately 15 feet per minute. The coefficient of kinetic friction was calculated by dividing the horizontal force required to keep the specimen in constant motion by the vertical or normal force, which included the applied load plus the weight of the block.

This coefficient was determined for the various materials both in a dry state and while water immersed. The latter was accomplished by placing the steel plate in a water-tight container and adding enough water so that a complete film covered the plate. The tests were then conducted in the manner previously described.

The coefficients of friction for the materials tested are listed in Table 8. From these data, it can be seen that the Lignum-vitae has a slightly higher average coefficient of kinetic friction than either the Arguto or Nylon, with the Nylon having the lowest average of all. The dry coefficient of kinetic friction of Lignum-vitae is higher than that of Arguto but much lower than those of Parock and Micarta and approximately equal to Nylon. The water-immersed end-grain Lignum-vitae showed the lowest coefficient of kinetic friction, while the water-immersed Micarta showed the highest.

Summary

The following summarizations can be made from the physical and mechanical properties of Lignum-vitae investigated in this study:

1. The shear strength of Lignum-vitae parallel to the grain is approximately equal to that of yellow birch.

2. Lignum-vitae has a hardness modulus which is about four times greater than that of yellow birch and sugar maple. Due to this hardness, the wood can be used as a self-lubricating bearing material under relatively heavy loads.

3. The toughness of Lignum-vitae is less than that of either sugar maple or yellow birch.

4. On exposure to a number of chemicals, it was found that only the 10 percent sodium hydroxide had a markedly greater effect on the weight and dimensional changes than did water alone. In many cases, the effects on these properties were less than that of water. The 10 percent sodium hydroxide also caused the most serious loss of abrasion resistance.

5. The effect of boiling water on the abrasion resistance of Lignum-vitae was to lower it nearly as much as did the action of the strong alkaline solution. It should be noted, however, that Lignum-vitae has found applications in boiling water with excellent relative wear life.

6. At sub-zero temperature the bearing characteristics of the Lignum-vitae, as measured by abrasion resistance, does not differ significantly from that of air-dry, untreated material.

7. The coefficients of friction of Lignum-vitae are generally comparable or superior to those of other materials used under conditions where a low-degree of surface friction is required. Service experience has indicated that, under certain conditions, the bearing surfaces of Lignum-vitae become glazed and slide after usage. This causes a lower coefficient of friction, which is in turn reflected in decreased power consumption. The self-lubricating property of the wood can never be lost, since the lubricating resin is distributed throughout the wood structure.

Literature Cited

1. Forest Products Laboratory. Wood Handbook. U.S.D.A. Handbook No. 72. Washington, D. C. 1955.
2. Record, Samuel J. and Robert W. Hess. Timbers of the New World. Yale University Press. New Haven, Conn. pp. 555–558. 1943.
3. Wangaard, F. F. The Mechanical Properties of Wood. John Wiley & Sons, Inc. New York. pp. 325–338. 1950.
4. Weatherwax, R. C., E. C. O. Erickson, and A. L. Stamm. A Means of Determining the Hardness of Wood and Modified Woods Over a Broad Specific Gravity Range. ASTM Bulletin No. 153. pp. 84–89. Aug. 1948.
5. World Timbers Vol. 2. The Timber Development Association, Ltd. London. pp. 40–42.

PULP AND CHEMICAL POTENTIAL FOR

Western Red Cedar Utilization[1]

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Improved kraft pulp utilization depends primarily on wood costs being low enough to compensate for the lower yield and production. Sulfite pulping has only limited promise, and groundwood production is not practical. Further research on all aspects of cedar extractives is needed before any conclusions can be drawn on chemical utilization, although the volatile oils show promise.

WESTERN RED CEDAR has become a utilization problem. While subject to some imbalances, there is a reasonable demand for the higher quality cedar that may be suitable for clear lumber or shingles. However, there are several sources of lower quality cedar not suitable for these uses.

One large source is slabs, edgings, trim, and other waste from lumber and shingle operations. Another source is the low-quality logs not suitable for such operations, that are a by-product of high-quality cedar or other logging operations. Probably the largest potential source and the one presenting the greatest long-range problem is the large volume of uncut scrub cedar. These trees have frequently been bypassed because of lack of outlets.

With the rapid growth of the pulp and paper industry in British Columbia, there has been increased utilization of waste wood to the point where the softwoods other than cedar are being moderately well utilized. The natural question is: Why hasn't this same development similarly improved the utilization of western red cedar? It is not because of lack of satisfactory pulping methods. Several workers (1, 2, 3) have demonstrated the suitability of the kraft process for pulping cedar, and several kraft mills pulp cedar commercially.

In addition to their work on kraft pulping, Drs. Holzer and Booth also showed that sulfite pulping could be applied to western red cedar (1). One phase of this discussion will be directed toward those factors which limit the use of cedar in spite of the presence in British Columbia of several large pulp and paper mills with the technical ability to utilize it.

Chemical Utilization a Potentiality

Chemical utilization of cedar has been suggested as another method of disposing of non-lumber quality wood. There is so little chemical utilization of either carbohydrate or lignin from wood, except via the pulp industry, that there seems little immediate potential for large-scale utilization of cedar in that area. However, the naval stores industries of the southern United States and the tannin industries amply demonstrate the potential for chemical utilization of the extraneous components of suitable woods. Gardner and Barton (4) in their summary of the extensive work on extractives from western red cedar, show that extractive content is high, so that this cedar could provide raw material for an extractives industry. Discussion will also be directed toward the problems to be overcome before the outlet becomes a reality.

Western red cedar *(Thuja plicata* Donn) is only one of the cedars available on the Pacific Coast. However, as it will be the only one considered here, the generic term, cedar, will be used for convenience in many cases to refer to it and it alone.

Pulp Utilization

Commercial kraft, groundwood, and sulfite pulp mills are all operating in British Columbia, so all three processes will be considered. However, as some general wood characteristics of cedar affect all these processes, they will be considered first.

Wood Properties

The peculiar characteristics of ceda markedly affect its utilization. Som properties affect only specific types o utilization and must be considered to gether with the method of utilization There are, however, two properties that affect most aspects of utilization and particularily pulping.

The low density of cedar is the most serious handicap to increased use in pulping. Pulp and, in many cases, paper are produced and sold on a weight basis. Therefore, a pulp manufacturer is basically interested in the weight of raw material that he obtains when purchasing wood. However, the logging and lumber industries normally work on a volume basis, with either a cord or a board foot measure for logs and a unit (200 cu. ft. gross volume) measure for chips, and it is on this basis that wood is usually sold. In the pulp industry on the West Coast, cedar is competing primarily against hemlock and Douglas-fir. The weight of a given volume of cedar is compared to that of the other woods in Table I.

Table 1.—DENSITIES OF CEDAR, HEMLOCK, AND DOUGLAS-FIR

Wood	Density, lb. of O.D. wood cu. ft. green volume	% of density of Douglas-fi
Cedar, (Oregon)	21.0	65
Cedar, normal, (B. C.)	21.5	66
Cedar, scrub, (B. C.)	23.0	71
Hemlock	27.9	86
Douglas-fir, old growth	32.4	100
Douglas-fir, second growth	31	96

These data were obtained within th Crown Zellerbach organization on numerous samples, and the results ar considered representative of British Columbia Coastal woods, except fo the Oregon cedar sample. Densitie

[1] Presented at the Fall Meeting of the Pacific Northwest Section, FPRS, Oct. 27, 1958, in Vancouver, British Columbia.

The Author: James Wethern holds a BS in chemical engineering from the University of Wisconsin, and MS and PhD degrees from the Institute of Paper Chemistry. He is Coordinator of Applied Research at Crown Zellerbach.

were determined by measuring volume by displacement and weight after drying and so are in terms of pounds of oven dry wood per cubic foot of green volume. These values are generally somewhat higher than reported in the literature (5), but it has been the author's experience that British Columbia woods are slightly denser than those from the northwestern United States, the wood source used in arriving at most of the wood-density figures cited in the literature.

This comparison shows that a given volume of cedar contains only 77 percent as much wood by weight as an equivalent volume of hemlock, or 66 percent as much as for old-growth Douglas-fir. This factor must be considered in evaluating cedar, together with the other factors that affect production costs.

The bark characteristics or cedar also affect utilization. The bark is quite stringy compared to that of other softwoods. The wood mill and debarking systems of most pulp mills are not equipped to handle this bark. Due to its stringy nature it becomes entangled in equipment. This plus low density reduces capacity so materially that wood mills designed for other woods could not satisfy production requirements if working on cedar. In addition, debarking costs are raised due to low capacity and high down-time for clean-up. While suitable equipment could be installed to overcome this problem, there normally has been no financial incentive to do so.

Another barking factor also affects utilization, cedar logs, particularly the lower grade ones, are often crooked and have ingrown bark. This results in incomplete bark removal in integrated wood mill operations, and also frequently results in significant bark content in waste chips. Any bark so included can cause dirt problems.

In addition to the above, the large percentage of irregularly shaped logs in pulp-quality cedar further hampers efficient wood mill operations at pulp mills.

Kraft Pulping

Kraft pulp production is the main commercial outlet for low-quality cedar today where value is greater than that of hog fuel and several kraft mills do use significant quantities. However, even though the British Columbia kraft mills have the capacity to use much more cedar, utilization remains poor. Several problems must be solved before larger scale utilization of western red cedar is undertaken.

Kraft pulping of western red cedar has been studied both at the Central Research Department of Crown Zellerbach and at the mills of Crown Zellerbach and Crown Zellerbach Canada Limited. As the laboratory results have been found to be generally comparable to those from mill work, and as more detailed information on the former are available, only the laboratory results will be reported here. Since the laboratory pulping and pulp evaluation procedures used have been reported elsewhere (1) they will not be covered here. Wood samples represent a mixture of chips from several trees and originated as follows: western red cedar from Columbia County, Oregon and from the Ocean Falls area of British Columbia; and western hemlock and old-growth and second-growth Douglas-fir from Vancouver Island, B. C. Results of kraft pulping are presented in Table 2.

The yield disadvantage of cedar mentioned under wood density is increased in kraft pulping due to lower yield of pulp per weight of wood. If both yield and density are taken into consideration, then on a volume basis western red cedar will give only 72 percent as much pulp as hemlock, or only 65 percent as much as old-growth Douglas-fir. This disadvantage shows up both in purchasing wood and in production. The kraft production problems, as far as the digestion stage is concerned, can be partially overcome by using chip packers to load more wood into the digesters.

Increased corrosion is another disadvantage in kraft pulping of western red cedar. To illustrate this problem, the case of Crown Zellerbach Canada's Ocean Falls mill can be cited. Here it was found that, due to rapid corrosion of the digester mild steel shell, the indicated life of a digester used exclusively on cedar was only 50 percent of that of the other digesters which were used on hemlock and Douglas-fir. In addition, at the Port Townsend mill, corrosion of the top or vapor dome of the digester has been a problem, and this problem has been found to be most serious with cedar.

The factors that cause this problem with cedar have been identified by MacLean and Gardner (6), and these findings have been confirmed by work at Crown Zellerbach's laboratories. The corrosion problem is made up of two distinct types, with one type due to volatile and the other due to non-volatile materials in cedar. That due to volatiles can occur in the following manner: When cedar chips are loaded into a digester, which is still hot from the previous cook as would be the normal case, the chips next to the shell are heated. This heat volatizes certain components from the cedar, primarily the isopropyl tropolones, α, β and γ thujaplicans.

When condensed, these chemicals react with either iron or iron oxides to form water-soluble iron salts. The action on iron is direct corrosion, while the action on iron oxides is to remove the protective film from otherwise passive areas, and lead to corrosion that would not occur without this activation. As condensation seems necessary, and as only limited areas, normally in the top of the digester, are cold enough for condensation, this corrosive action is concentrated in such areas.

The exact nature of the non-volatile materials in western red cedar that cause corrosion is not clearly defined, although available information indicates that they are phenolic, probably containing 1,2-dihydroxybenzene groups. The responsible materials apparently have a chelating action on iron, even in alkaline media, and form water-soluble iron complexes.

Installation of corrosion-resistant materials to permit kraft pulping of cedar is not so straightforward a solution as it might appear to those not familiar with a kraft mill. The cost of such equipment will run from 50 to 200 percent more than for the normally used steel equipment; thus, inclusion of such equipment may increase the capital investment in a modern kraft mill by millions of dollars.

The use of anodic protection of kraft digesters has been studied by Mueller (8). It would be desirable to know if this would be effective in preventing corrosion due to cedar. The possibilities of an extractives industry based on cedar will be discussed later in this paper. It might be pointed out, however, that since it has been demonstrated that removal of the extractives eliminates the unusual corrosion due to cedar (6), a wood residue from such an industry might involve no unusual corrosion problem. This should serve as an added incentive to development of such utilization, since removal of the extractives only to eliminate corrosion would almost certainly be too expensive. Mixing cedar with other woods during pulping may be a partial answer to corrosion as there have been some indications that addition of no more than 25 percent cedar to Douglas-fir cooks results in a corrosion rate more in line with that expected for Douglas-fir than for cedar. However, further studies are needed to verify this tentative result.

The one bright spot in kraft pulp utilization of cedar is that kraft pulp from cedar does have some quality advantages over competing softwoods pulps. (Table 2).

Hemlock kraft pulp has been found through experience to have a very nearly optimum strength balance, for a softwood pulp, of strength properties for many critical grades such as bag and sack papers. A comparison of

hemlock, cedar, and Douglas-fir pulp strength properties shows cedar to be superior in bursting and tensile strengths but deficient in tear compared to hemlock, and the reverse situation to be true with Douglas-fir. Since Douglas-fir is the preferred lumber species, large amounts of Douglas-fir wastes are available, but utilization is hampered by the above strength properties. Because of the complementary strength relationship, however, proper mixtures of Douglas-fir and cedar pulps are approximately equivalent to hemlock in properties. This ability of cedar to "up-grade" Douglas-fir to hemlock quality is its main advantage in the kraft pulp utilization field.

Table 2.—KRAFT PULPING COMPARISON OF WESTERN RED CEDAR[1]

Wood and Source	Oregon cedar	Oregon cedar	British Columbia cedar	Hemlock	Second-growth Douglas-fir	Old-growth Douglas-fir
Wood Condition	Barked	Unbarked	Barked	Barked	Barked	Barked
Chemical usage, Na_2O based on O.D. wood, %	15	16	15	15	15	15
Time at max. temp., min.	95	100	95	90	90	90
Screened yield, %	42.3	42.1	41.7	44.5	45.1	42.5
Screenings, %	1.4	2.2	2.6	3.0	3.0	2.6
Permanganate number	26.1	28.8	27.1	28.0	27.1	27.2
G.E.R.S. brightness, at 460 mmu	26.8	21.1	21.3	22	22	21.3
Pulp strength at 600 cc C.S.F.						
Bursting strength, pt./100 lb. basis weight	200	169	207	165	135	125
Tearing resistance, gm/lb. basis weight	1.98	1.92	1.72	2.25	2.75	2.85
Breaking length, meters	14,500	12,600	14,400	12,000	11,000	10,150
Apparent density, g./cc	.73	.70	.71	.68	.65	.62

[1]Constant Conditions—Time to temperature—60 min.; Temperature, 345° F.; Sulfidity 24-26%; Liquor ratio 3.5-4.0:1.

Bark elimination can be a problem with cedar, as mentioned earlier. To determine the importance of bark in kraft pulping, cooks were made on chips from unbarked cedar logs. Results are shown in Table 2. A higher chemical usage was found to be necessary with the unbarked wood, if it was to be pulped to the same degree as the debarked wood. Even at this higher chemical usage, the bark caused a significant drop in strength and brightness. Also dirt and shive counts were increased to the point where they would be objectionable in many unbleached grades. The effect of bark on bleaching was also determined by running comparable four-stage bleaches on pulps from unbarked and debarked wood. The overall conclusion is that cedar bark is deleterious to pulp quality and should be largely eliminated in a cedar supply for kraft pulping, although the small amount that might get into chips from ingrown bark seams, and so forth should not have too serious an effect.

Groundwood Pulping

With the large newsprint production in British Columbia, if groundwork production from western red cedar were practical, considerable utilization might result. Unfortunately, this is impractical because of the poor color of cedar groundwood. While the sapwood of cedar is fairly light, and might give a good groundwood, practically all available wood contains a significant percentage of dark heartwood. This heartwood lowers brightness, a measure of pulp whiteness, to an unacceptable level. For example, a representative sample of cedar when ground gave a brightness of 38, compared to a brightness of about 55–60 for the West Coast softwoods commonly ground for newsprint groundwood. Hydrosulfite bleaching is commonly used to improve brightness of groundwood pulps. However, a bleach of cedar groundwood using 2 percent of sodium hydrosulfite and proper other conditions raised brightness only to 48. Thus, even though a larger amount of chemicals than usual was applied, brightness was still below the acceptable level. Because of color, little work has been done on the other aspects of grinding cedar. From wood properties it is expected that groundwood pulps of reasonable strength might be obtained from cedar. However, grinding of cedar for papermaking pulp must await development of suitable pulp bleaching techniques.

Sulfite Pulping

Sulfite pulp production in British Columbia is sufficient to utilize much of the available cedar, but available information indicates such cedar use is insignificant. This is in spite of the fact that sulfite pulping of western red cedar has been demonstrated to be possible (1). Further studies have been made at both the Port Angeles and Camas, Washington mills and at the Central Research Department of Crown Zellerbach on the problems to be overcome to make increased commercialization practical. Again, laboratory studies duplicate mill experience and so are used for convenience. Pulping procedures have been covered elsewhere (1) so only the results as shown in Table 3 will be reported here. Wood sources were as reported under kraft pulping, except the scrub cedar sample was from the Ocean Falls area of British Columbia.

Cedar does have a yield disadvantage compared to hemlock, primarily due to low density. This may be further increased by low yield in pulping of cedar, especially if it contains a high concentration of extractives. This appears to be the main reason for the differences in yield between the various cedar samples.

Digestion production rate suffers from this low yield per volume, but is further aggravated by the long cooking time required for pulping order. In the experimental cooks, there was a 1.8 hour increase in cooking time over an 8 hour hemlock cycle. This is equivalent to a 22 percent longer cooking time, and commercial experience confirms that it is necessary to increase the overall cycle by about this amount. This imposes a very severe obstacle in sulfite pulp utilization of cedar, because of the higher operating and capital costs that result from this low production rate.

There are several other problems in the sulfite pulping of cedar. Chemical usage is very nearly as large per digester of cedar as per digester of hemlock, so chemical costs are raised accordingly. The cedar sulfite has a low initial freeness, which indicates a low drainage rate of water through the pulp. This slows washing of the pulp in sulfite blow-pits and otherwise limits production rate. Another factor on the negative side may be corrosion, although the materials used in a sulfite mill are normally quite corrosion resistant, and no difficulties have been noted in limited laboratory and mill experience. However, the extractives which cause difficulty in kraft pulping are strong enough chelating agents so that it would seem desirable to check corrosion possibilities before extensive use of cedar in a sulfite mill.

Bark creates a special problem in sulfite pulping of cedar. This problem is so severe as to make use of unbarked wood impractical with present screening methods. Even traces of bark can cause a significant problem of this type and lead to dirt in the final product, so very thorough debarking is necessary.

High dirt content and low brightness are a problem with cedar even if no bark is present. Such dirt appears to be due to a larger than normal break-up of knots, perhaps due to the long cooking time required for the wood. This dirt can be reasonably well removed by centrifugal cleaners. The low brightness is a serious problem, for it would limit usage of unbleached cedar sulfite to only a few of the paper grades where unbleached sulfite is nor-

Table 3.—SULFITE PULPING OF WESTERN RED CEDAR[1]

Wood and source	Oregon cedar	Oregon cedar	B. C. normal cedar	B. C. scrub cedar	B. C. hemlock
Wood condition	Barked	Unbarked	Barked	Barked	Barked
Time at temperature	5.42	5.58	5.30	5.30	3.50
Yield, %	41.0	37.9	47.3	44.0	46.48
Screenings, %	2.7	7.4	1.2	2.9	1–2
Permanganate No.	14.5	15.6	11.1	16.6	12–16
Brightness, G.E.R.S. at 460 mmu	44.4	40.4	43.7	41.5	55–60
Initial freeness, cc, C.S.F.	660	610	665	675	700–720
Strength properties at 600 cc C.S.F.					
Bursting strength, pt./100 lb.	135	104	158	131	120
Tearing resistance, g/lb.	1.26	1.25	1.12	1.23	1.30
Breaking length, M.	11,800	8,550	11,800	9,700	10,800
Apparent density, g/cc	.76	.72	------	------	.69

[1]Constant conditions: Base—calcium; total sulfar dioxide, %—6.90–7.10; combined sulfur dioxide, %—1.18–1.22; maximum temperature 280° F.; time to temperature—4.5 hr.; maximum pressure—95 psig; blowdown time—1.25 hr.; blow pressure—35 psig.

mally used. Bleaching to overcome this brightness is possible. It should be noted that cedar sulfite seems more susceptible to degradation during bleaching than most sulfite pulps, probably due to the drastic nature of the cook required for pulping.

Strength properties of cedar sulfite are nearly its sole advantage; as compared to hemlock, bursting strength is high although tearing resistance is low. Strengths are not high enough to permit any unusual uses, however. The other advantage of cedar sulfite is its excellent forming characteristics as compared to hemlock sulfite.

Chemical Utilization

The production of chemicals has been suggested as one possible answer to improving cedar utilization. For this, there seems little reason to look especially at the carbohydrate or lignin fractions, for these cedar components do not appear to have an unusual properties, and there is practically no commercial chemical utilization of these materials except via the pulp industry. Furthermore, because of low density, for any uses involving cellulose or lignin, cedar would suffer from the same low yield per volume of wood problem as mentioned under pulping.

Chemical utilization of the extractive fraction of cedar offers more attractive possibilities. The total extractive content of cedar is appreciably higher than that of woods such as hemlock or Douglas-fir, and may amount to as much as 30 percent in selected parts of cedar stumps. However, the total extractive content of most of the wood, which for cost reasons might be classed as available for this type of utilization, is considerably lower than this. The extractive content of cedar is highest in the more mature trees, especially in those growing under more favorable conditions, and many of the figures on extractive contents cited in the literature appeared to be based on studies of such woods. These are the trees least likely to be available, however, because they are the best trees for lumber and shingle operations.

On the presently harvested logs, the extractive content is highest in the butt logs, and near the edge of the heartwood, that fraction of the tree which is most likely to be utilized by present means. The waste wood from such operations commonly contains large percentages of sapwood, which has practically no extractive content. Limited tests have been made on scrub and other lowgrade cedar, the wood other than sawmill waste most likely to be available, and contents of acetone-soluble extractives of as low as 3 percent have been noted on individual samples representative of all of that part of a whole tree normally removed from the forest. The wood available for extractive utilization no doubt has an extractive content somewhere between these relatively wide limits of 3 to 30 percent; more extensive surveys of extractive contents on available woods are needed to establish realistically the potential of cedar extractives production.

Sawdust and shavings from sawmill operations, and tow from shingle mills are probably the most attractive raw materials at present, for they should be available at low cost and have reasonably high extractive contents. Cedar stumps might be attractive, if they could be collected at low enough cost. However, before any conclusions on the potential of various raw material sources can be drawn, the methods of recovering and the type of materials present in the extractives must be considered. For convenience, discussion on these points will be divided into two parts, with volatile and nonvolatile extractives considered separately.

Volatile Oils

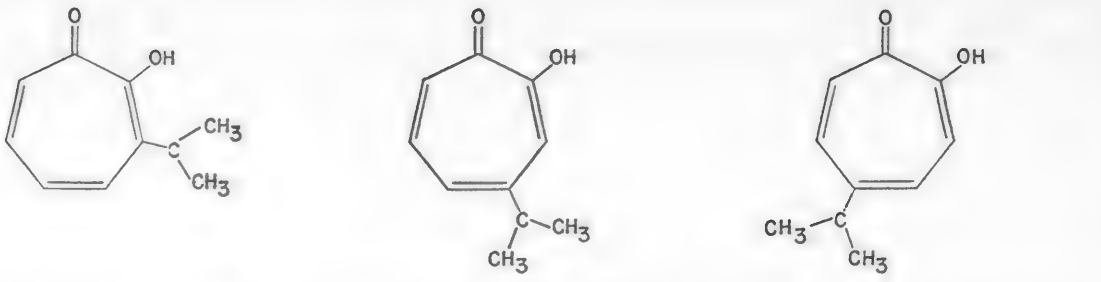
The fraction of cedar that has received the most attention for chemical utilization is the volatile oils. Gardner and Barton (4) reported that a sample of such oil recovered in 0.3 percent yield from a mill-run sawdust contained approximately one part thujaplicins, one part thujic acid, and two parts methyl thujate. The amount and ratio of these materials will vary with the source. In addition, there apparently are other components present, but in amounts too small to be of much commercial interest. The thujaplicins consist primarily of three closely related chemicals, α, β and γ thujaplicin, which have chemical structures as shown in Fig. 1. Gardner and coworkers et al (9) have also shown the presence of another slightly different compound, 7 hydroxy-4 isopropyltropolone, which is also shown structurally in the attached figure. The thujic acid and its methyl ester are pure chemicals, and their structures are also shown. Sources containing more detailed information on the chemistry of these materials have recently been reviewed (4), so the chemistry of these materials will not be described further here.

Suggested uses for the thujaplicins have included application in insecticides, fungicides and antibiotics, since thujaplicins show natural activity in these areas, and they might well be even more effective if suitably chemically modified. Their chelating ability has also been the basis for other suggested applications. In addition to normal chelating applications, many of the metal chelates are soluble in organic solvents. Thus, they may have special application in metal separation or purification, or as catalysts.

Thujic acid and methyl thujate have been suggested as base materials for the perfume and odorant fields. This use is based on the distinctive odor of the methyl ester, which is mainly responsible for the characteristic cedar smell, and on the fact that other unusual odors can be achieved by producing chemical derivatives of the acid. Use of thujic acid and derivatives in insecticides, especially for carpet beetles and clothes moths, has also been suggested (4). In addition, thujic acid and the thujaplicins from cedar are among the few sources of naturally occurring compounds that have seven-carbon atom rings. This unusual chemical structure may lead to unique properties and may make these chemicals suitable as base materials for the development of many new agents in the pharmaceutical field.

In view of the relatively low concentrations of these materials in available raw materials, any commercial uses would almost certainly have to justify a high price. Furthermore, the above are only suggested uses, and considerably more research will be required before commercial demand develops for these materials.

Isolation might be a problem, even if commercial demand developed, since



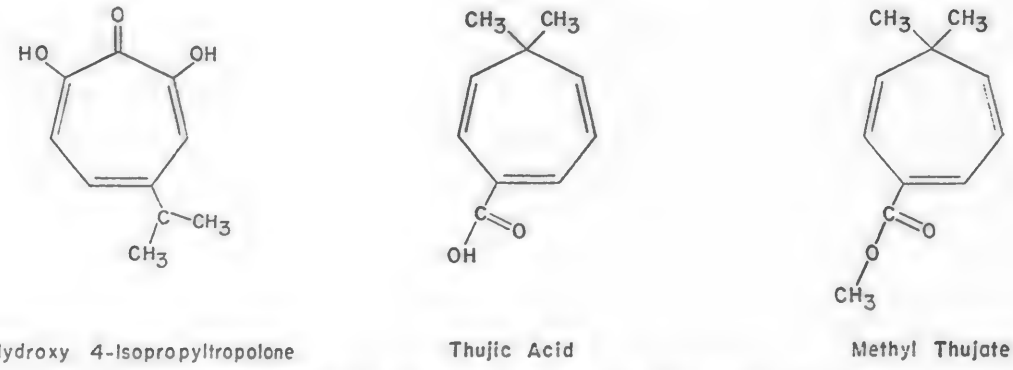


Fig. 1.—The most important chemicals that have been isolated from the volatile oils of western red cedar.

there are no publicized commercially proven methods of isolating these volatile oils from the wood and purifying the individual components. This problem is complicated by the low concentration of these materials in most available waste wood, as indicated by the 0.3 percent yield from mill-run sawdust cited earlier. Steam distillation can be used, but steam requirements are high and separation from the water condensate presents a problem because of water solubility. Gardner and Barton (4) have suggested the use of copper wire or powder to recover the thujaplicins only from the vapor space of dry kilns operating on cedar, or from the vapor phase of a steam stripping operation. Copper has a selective action, as it reacts only with the thujaplicins in the volatile oils, and the resulting chelate can be readily decomposed to permit recovery of the desired material. Solvent extraction could be used to separate the materials from wood, but a fractionation would be involved in obtaining pure materials. Alkaline extraction and a fractionation procedure to recover thujic acid has been patented (10). The thujaplicins are also removed from cedar by this type of extraction, and are recoverable via solvent extraction or other means from the acidified extract.

The thujaplicins are stable enough so that a major portion are present in the waste liquor from either kraft or sulfite cooks of cedar. Isolation of thujaplicins from pulping waste liquors may thus be a possibility, especially if pulping of cedar increases. Unfortunately, thujic acid is largely decomposed by either type of cook, and thus is not practically recoverable from pulping waste liquors. While these are only a portion of the several potential isolation schemes, all apparently require more work before any commercial utilization of volatile cedar oils is undertaken.

Non-Volatile Extractives

The amount of non-volatile extractives is normally considerably larger than that of the volatile oils, so it might be expected that the former would be of more interest for utilization. In general, this has not been the case; with only a few exceptions, these non-volatile materials do not appear to have been considered for utilization so information on their applications, isolation, and so forth is limited.

The phenolic materials are the largest component of the non-volatile fraction, although cedar does contain small amounts of arabinose and a sterol (4). No special uses have been suggested for the sugar, arabinose, and so little work has been done on the sterol that there is little basis for suggesting uses. The phenolic materials constitute at least 5 percent of most available wood, and may amount to 20 percent in some cases, so relatively large amounts could be obtained if found to be of sufficient value. The phenolic properties have been the main basis for suggested uses, and include applications such as anti-oxidants, oil-well drilling muds, dispersing agents, and extenders or modifiers for phenolic resins.

The presence of pyrocatechol groups (4) has also suggested application as a chelating agent in various fields. Unfortunately, these phenolic compounds have not been well enough physically or chemically characterized to provide a good basis for scientific selection of applications. Further fractionation and studies of the type being carried out by Gardner and Barton (4), which incidentally have led to isolation of what appears to be a new compound, plicatic acid; would seem to be necessary as the first step to commercial utilization of these materials.

Consideration of commercial isolation may be somewhat premature in view of the above, but it would seem best accomplished by extraction with either solvent or aqueous alkali solutions. Either would also serve to separate the volatile oils from wood. Because a mixture of materials would be obtained by such isolation methods, fractionation into individual components might also be desirable for commercial uses. However more work on properties and potential uses is required before extensive work on isolation and purification of fractions seems justified.

Bark

Cedar bark has been shown to contain many of the same extractives as the wood (11), and extractive content is high. Thus, while perhaps not contributing as directly to improving utilization of cedar, bark should be included in any consideration of extractives from cedar.

Summary

Western red cedar is pulpable by either the kraft or sulfite process, but yields too dark a groundwork to have any possibility for groundwood production. Low wood density must be otherwise compensated for if cedar is to be competitive. Bark characteristics complicate pulping utilization.

Kraft pulp yields and digester productive capacity with cedar are lower than for competitive woods. Increased corrosion is another disadvantage. Cedar kraft pulp does have superior properties for many uses. However, the value of this strength is limited, and does not compensate in practice for the disadvantages cited. Development of improved methods of handling corrosion would reduce but by no means eliminate the over-all disadvantage.

Sulfite pulp production from cedar suffers from a severe production penalty. Dirt, poor color, high chemical usage, poor drainage, and extreme operating difficulties with any bark are other sulfite pulping problems. The slight strength and formation advantages with cedar sulfite pulp do not nearly compensate for other disadvantages, and therefore kraft pulping is preferred over sulfite for cedar.

Chemical utilization of cedar will depend on finding uses for the extractives. This must be classed as a long-range approach to utilization, because more research and development work is needed on both the methods of isolation and commercial application of the various extractives in cedar. More extensive surveys on the extractive content of waste cedar from various sources is also needed to determine which of the various materials would offer the lowest cost source of extractives.

Over-all, with exception of corrosion, kraft pulping utilization is more dependent on economic than technical factors, so the need for research in this area is limited. In chemical utilization, additional research on all technical aspects is needed before any economic evaluation can be made.

Literature Cited

1. Holzer, W. F., and K. G. Booth. 1950. The characteristics of unbleached kraft pulps from western hemlock, Douglas-fir, western red cedar, loblolly pine, and black spruce, III. The comparative pulping of the woods. Tappi, 33 (2): 95.
2. Bray, M. W., and J. S. Martin. 1947. Sulphate pulping of Douglas-fir, western hemlock, Pacific silver fir, and western red cedar logging and sawmill waste. Tappi Section P.T.J. 125 (16): 40.
3. Christiansen, C. B., J. S. Hart, and J. H. Ross. 1957. Sulphidity as a variable in the pulping of western red cedar. Pulp and Paper Mag. Can. 58 (1): 103.
4. Gardner, J. A. F. and G. M. Barton. 1958. The extraneous components of western red cedar. Forest Prod. J. VIII (6): 3.
5. Isenberg, I. H. 1943. Properties of pulpwoods. 1st Edition, The Institute of Paper Chemistry, Appleton, Wis.
6. MacLean, Harold, and J. A. F. Gardner. 1953. Heartwood extractives in digester corrosion. Pulp and Paper Mag. Can. (11): 125.
7. Flynn, F. W., F. H. Richter and F. R. Snyder. 1953. Uneven corrosion in alkaline pulping digesters. Tappi Vol. 36, No. 10: p. 433.
8. Mueller, W. A. 1958. Anodic protection of alkaline pulping digesters. Paper awaiting publication.
9. Gardner, J. A. F., G. M. Barton and H. MacLean. 1957. Occurrence of 2, 7-Dihydroxy-4-Isopropyl-2, 4, 6-cycloheptatrien-1-one (7-hydroxy-4-isopropyltropolone) in western red cedar (Thuja plicata Donn.) Chem. of Can. 35: p. 1039.
10. Van Beckum, W. G. 1951. U.S. Patent No. 2,541,127, Feb. 13.
11. Smith, J. E. and E. F. Kurth. 1953. The chemical nature of cedar bark. Tappi 36, No. 2: 71.

UTILIZING RESIDUES FROM

Western Red Cedar Mills[1]

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Sawdust, a major mill residue, may be briquetted for fuel. Pulp chips are an important outlet, but digester corrosion is a limiting factor. Extracting chips would recover chemicals, reduce corrosion.

WESTERN RED CEDAR in British Columbia reaches its optimum growth on the coast where it occurs as far north as the Naas River. It is seldom found in pure stands, but usually in association with hemlock, balsam, and Douglas-fir. Because the coastal forests do not lend themselves to selective logging, cedar is taken from the woods with fir and hemlock. In the mature stands of the south-coast forests, the cedar types make up 34 percent, and in the north-coast forests 52 percent, of the merchantable volume.

The latest British Columbia Forest Service inventory (1)[3] shows that, of the sound wood in accessible mature commercial forests, under close utilization standards there are 60 billion cubic feet on the coast of which 23.4 percent is cedar, and 120 billion cubic feet in the interior of which 4.6 percent is cedar. In the interior, there are special problems associated with the harvesting of cedar that will not be discussed in this paper.

The actual log cut of cedar has remained quite steady on the coast in the past 10 years. It reached a peak in 1955 of 829 million ft.b.m. and dropped to a low of 603 million ft.b.m. in 1952. The percentage of the total cut on the coast shows even less fluctuation, with an average of 20 percent, a high of 22.2 percent in 1948, and a low of 18.0 percent in 1953.

Western red cedar is one of the most durable softwoods. Its light weight, low shrinkage factor, high insulating value, soft, even texture, warm color, and ease of working are characteristics that make this wood especially valuable for lumber and shingles. In the past 10 years, the cedar cut for lumber has increased from 12.2 percent to 16.3 percent, and at the peak year was 17.8 percent of the total lumber produced.

[1] Presented at the Fall Meeting of the Pacific Northwest Section, FPRS, Oct. 27, 1958, Vancouver, British Columbia.
[2] The Forest Products Laboratories of Canada are a Division of the Forestry Branch, Department of Northern Affairs and National Resources.
[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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In this same period, western red cedar shingle production dropped from 2.5 to 1.7 million squares per year.

Thus the drop in shingle production has been balanced by the increase in lumber production.

From Roof Shingles to Sidewall Shakes

In the post-war years, the market for roof shingles (16 inch) suffered from increased competition with asphalt shingles, with the result that at the present time only 15 to 20 percent of the shingle production goes into roofing.

To fill this gap, the red cedar shingle industry has done an excellent job of developing and marketing side wall shakes (18 inch). These are precision squared and rebutted. They are marketed in several refined forms such as grooved, sanded, pre-stained and pre-painted. Others are assembled into panels of various types for speed of application.

The sharp decrease in the percentage of Douglas-fir lumber cut and the increase in the cut of hemlock lumber and pulp logs will probably be associated with an increase in the cut of cedar and other species.

In the last decade the percentage of cedar log grades has undergone a considerable change from 13 percent No. 1, 40 percent No. 2, and 47 percent No. 3 in 1948 to 11 percent No. 1, 28 percent No. 2, and 61 percent No. 3 in 1956.

Cedar is a wood that is soft in texture, and the characteristic of splitting easily on a radial face is both an advantage and a disadvantage. It is a desirable property in the manufacture of hand-split shakes, but when trees are felled on rough side hills and logged with heavy machinery, the logs often end up in pieces or with very serious splits and shattered areas. In sawmills the soft texture of the wood frequently results in damaged areas, which must be removed by trimming and ripping. These factors affect the utilization of cedar as lumber and, combined with bark seams, flared butts, and hollow butts make cedar a difficult species on which to predict the yield in lumber or to obtain an accurate scale. As a result, the board-foot scale and the cubic scale are not true measures of the wood volume in a log.

Three distinct types of logs are recognized—lumber logs, merch logs, and shingle logs.

The lumber log is large, usually grade 1 or 2, and will produce a high percentage of clear lumber. Figures on log grades show that the quantity of this class of log is gradually decreasing. Replacing the lumber log is the merch or common log, usually of grade No. 3 and considerably smaller. The product of this log is tight-knotted cedar for which a market has been developed for knotty panelling, roof decking, knotty siding, and so forth.

The process of manufacturing lumber from cedar logs involves much trimming and ripping to eliminate defects and to produce as much high value, clear lumber as possible (even from the merch logs the percentage of clear is quite a significant factor). As a result the recovery is low in comparison with other species.

Shingle logs are usually rather large grade 2 and 3 logs that are quite rough and unsuitable for lumber. They will produce clear, straight-grained shingles between the knots, however.

Table 1.—LUMBER PRODUCTION BY SPECIES—COACT MILLS, 1948–1957 (2)

Year	Total lumber volume, M ft. b.m.	Percentage of lumber cut				Shingle production (Thousands of squares)
		D.-fir	Hemlock	Cedar	Others	
1948	2,037	57.8	25.8	12.2	4.2	2,505
1949	2,139	59.8	23.4	12.2	4.6	2,781
1950	2,568	58.6	25.3	11.3	4.8	3,363
1951	2,499	56.4	27.2	12.2	4.2	3,126
1952	2,224	54.7	27.9	13.7	3.7	2,519
1953	2,580	53.6	28.1	15.2	3.1	2,638
1954	2,707	51.7	27.8	16.9	3.6	2,669
1955	2,775	49.0	29.1	17.6	4.3	2,516
1956	2,525	46.3	30.4	17.8	5.5	2,003
1957	2,325	43.8	35.2	16.3	4.7	1,695

Sawmill Residues

The Vancouver Laboratory of the Forest Products Laboratories of Canada recently measured sawmill residues between log pond and green chain at three sawmills that cut merch or common type cedar logs. The mills were of the 50 to 75 M per 8-hour shift class, and were equipped as follows:

1. Band head-saw, cant-gang and edger and double-end trim saws.
2. Band head-saw, band re-saw, edger and double-end trim saws.
3. Double-circular head-saw, cant-gang, edger and double-end trim saws. This mill also used a band re-saw and pony edger for remanufacture of miscut pieces.

In all, 163 M ft.b.m. of logs were examined; they ranged in top diameter from 7 inches to 30 inches.

The residues at two shingle mills were measured. In each case the blocks from individual logs were directed to one sawyer, because it was difficult to measure the residues from the whole operation. Logs with a total net scale of 9,131 ft.b.m. were studied.

The results obtained from measurements of residues at three sawmills are based on the cubic volume of the logs when measured as sound wood content with deductions made only for rot or lack of wood. This was done to give a realistic value to the cubic volume of wood going into the mills. The board-foot scale was taken as the log scale measured in the boom. (All three mills bucked the logs into short logs in the pond.)

Sawdust: The total volume of sawdust produced averaged 18.7 percent of the cubic log volume, and amounted to 44.6 cubic feet of solid wood per M ft.b.m. log scale. This represents 0.56 units per M ft.b.m. or 940 pounds bone-dry weight per M ft.b.m.

The industry in 1957 would therefore have made approximately 175,000 bone-dry tons of cedar sawdust.

Sawdust volumes were very similar in spite of the different methods of cutting. The circular mill had the lowest percentage of sawdust (17.4 percent) because a considerable part of the cut was made up of small timbers. This mill operated a small cant-gang intermittently on the class of logs cut during the study. However, the small size of the logs made the cubic volume per M ft.b.m. higher than the other mills. The high percentage of defects in the defective log sort at one mill re-

Table 2.—SAWDUST PRODUCED FROM ONE THOUSAND BOARD FEET LOG SCALE (PERCENTAGES BASED ON CUBIC LOG VOLUME)

Mill No.	Volume per M ft.b.m. Log Scale											Av. top dia. ins.
	Head-saw		Gang-saw		Edger		Trim-saw		Total			
	cu. ft.	%	cu. ft.	%	cu. ft.	%	cu. ft.	%	cu. ft.	%	Units[2]	
1	13.2	5.4	29.1	12.1	5.0	2.1	0.2	0.1	47.5	19.7	0.59	15
2	18.8	9.1	15.2[1]	7.4[1]	5.2	2.5	0.2	0.1	39.4	19.1	0.49	20
3	36.6	13.6	1.2	0.4	8.8	3.3	0.3	0.1	46.9	17.4	0.59	12
Av.	22.9	9.4	15.2	6.6	6.3	2.6	0.2	0.1	44.6	18.7	0.56	

[1] Resaw.
[2] 1 unit = 80 cu. ft. solid wood.

sulted in a very high volume of sawdust per M ft.b.m.

Solid Residues: The total volume of slabs, edgings and trims was 44.9 cubic feet per M ft.b.m. log scale, which was equivalent to 0.6 cords or 18.3 percent of the cubic volume of wood going into the mill.

The solid residues are shown in the following table:

Table 3.—SOLID RESIDUE PRODUCED FROM ONE THOUSAND BOARD FEET LOG SCALE (PERCENTAGES BASED ON CUBIC LOG VOLUME)

	Volume per M ft.b.m. Log Scale								
	Slabwood		Edgings		Trimmings		Total		
Mill No.	cu. ft.	%	cu. ft.	%	cu. ft.	%	cu. ft.	%	Cords[1]
1	14.1	5.7	15.9	6.4	12.1	4.8	42.1	16.9	0.56
2	22.1	10.6	11.9	5.6	2.6	1.3	36.6	17.5	0.49
3	14.5	5.3	27.9	10.3	13.7	5.0	56.1	20.6	0.75
Av.	16.9	7.2	18.6	7.4	9.4	3.7	44.9	18.3	0.60

[1] 1 Cord = 75 cu. ft. solid wood.

In 1957 the total solid residue produced by the industry amounted to 175,000 bone-dry tons.

If the logs were barked, the potential volume of pulp chips would be 0.67 units per M ft.b.m. log scale.

Log size is a factor that considerably affects the volume of solid residue, especially in the smaller diameters. In one mill the logs were segregated into size and quality groups. The better quality logs were cut into 5/4 boards for siding. The size of larger groups averaged 15.8 inches top diameter, and of a medium group 11.9 inches top diameter. The difference in solid residue was 4.1 percentage points—13.7 for the large group compared to 17.8 percent for the medium group. The relative volumes of both slabs and edgings were higher for the smaller logs.

Defective logs also yielded a larger volume of solid residues than sound logs of comparable size—19.3 percent compared to 13.7 percent.

One mill with a lath machine processed 30 percent of the slabs and edgings made in the sawmill and recovered 31 percent of this volume as lath. Thus another 2.3 percent of net cubic volume was utilized.

Beyond the green chain further heavy losses occur. In the planing mill, the volume of wood lost by trimming and ripping is high. At one mill the policy was to trim, in the sawmill, only the very obvious defects to obtain square ends for planing and then the main trimming was done in the planing mill. A study showed a comparatively heavy loss which amounted to 12.9 percent of the lumber volume on a run of kiln-dried 1 by 8 boards, and 11.5 percent on green 1 by 8 boards. On the basis of log volume, this loss would be on the order of 8 percent.

When manufacturing siding the losses vary from 10 to 20 percent from trims, cut outs, and fall downs. Cedar producers are very conscious of utilization, and markets have been found for short clears and siding down to two feet in length.

In sawmills that cut common type cedar logs, the recovery of rough green lumber was found to be 63 percent of the cubic log volume. When final rimming is taken into account, however, the net lumber recovery is smaller.

In addition there are large quantities of planer shavings. The thickness of the rough lumber is the deciding factor in the volume of wood made into shavings. When a rough green 1¼ by 10¼ piece of lumber is dried and made into ¾ by 10 beveled siding, the planer shavings and sawdust amount to 27.5 percent of the green volume.

Shingle Mill Residues

Data obtained at two mills showed that in the manufacture of perfection shingles (18 inch) the net cubic volume of the logs was broken down in the following proportions:

	Percent
Shingles	40.2
Cut-off saw	4.9
Knee bolter and splitter	4.1
Spalts	8.8
Splints	14.1
Sawdust (shingle machine)	27.9
Total	100.0
Total sawdust residue	32.7
Total solid residue	27.1

The shingles constitute about 2/5 of the log volume. The next largest element is sawdust—about 1/3 of the log volume. The greater part is made at the shingle saw, with only small amounts developing at the cut-off saw on the deck and at the knee bolter.

The solid residue consisted mostly of spalts—triangular pieces usually about 2½ by 5 inches—and splints—the narrow trims from the edges of the shingles. In addition, the trims from the ends of the logs and the wood cut off at the knee bolter made up 4.2 percent.

It is estimated that in 1957 a total of 24 million cubic feet of solid wood was made into cedar residues in the manufacture of shingles on the British Columbia coast.

Bark: The stringy and tough nature of cedar bark makes it a probelm in the mill, where it becomes wrapped around moving parts. Hydraulic barkers will remove it successfully but trouble is experienced with mechanical barkers.

Bark was not included in these residue percentages, but a separate study showed that, for every 100 cubic feet of wood, there are 6.9 cubic feet of bark if the logs are completely covered with bark. Mill-run figures indicated that there was only 5.3 cubic feet left on the logs by the time they arrived at the sawmill. On a board-feet log scale basis, this amounted to 16.9 cubic feet of bark per M ft.b.m. log scale if there was 100 percent bark coverage, and 13.1 cubic feet per M ft.b.m. on a mill-run basis.

Utilization: Of the large volume of residues produced, only a small percentage is presently utilized. It is difficult to estimate the volumes of residues used, but some present and potential uses are outlined in the following paragraphs.

Bark: The only use to date for cedar bark has been as fuel mixed with sawdust, shavings, and other hogged material. The calorific value of 8,700 Btu per pound of bone-dry material is lower than that of the wood, which has a value of 9,700 Btu per pound.

Bark is fibrous in nature and can be defibred and pulped. Hardboard and insulating boards of acceptable standards can be made from mixtures of western red cedar bark and wood (4,5).

Sawdust: Sawdust constitutes a high percentage of the residue in a cedar operation because most of the lumber is produced in one-inch material. The only real use for this has been to make briquettes for fuel. One lumber mill and one shingle mill are making briquettes of dried sawdust and hogged material. In 1956 (6), 19,000 tons of briquettes valued at $265,000 were produced.

Sawdust is used mostly for fuel in the mill boilers and mixed with hogged fuel. Some mills generate all the power used from cedar residues.

Planer shavings are utilized for cattle bedding.

Solid residues: Lath and shingle bands are used for solid residues, but these markets are limited. In 1956 (6) the value of lath used was $350,000, of which cedar lath was probably 50 percent. Shingle bands produced were valued at $84,000. Fence pickets are another use for shorts—pieces 1 inch by 3 inches by 3 feet are saved.

Pulp chips are an important outlet for solid material. Their use is limited, however, because pulp mills use only up to 20 percent for blending with

other pulps. Some mills do not use any cedar because of its corrosive properties. In 1957, out of the 1,500,000 units of chips produced in British Columbia probably 10 percent were cedar. At the present time the market is restricted, but the cedar mills that now produce chips have a potential of 165,000 units, or about 11 percent. The value of cedar chips is about 60 percent of the hemlock chip price. A mill without a barker can expect about 0.3 to 0.4 unit of chips per M ft.b.m. log scale.

Other uses for solid residues are for tie plugs, cut stock for luggage, furniture, toys, and cores of flush doors. One mill saves 2- and 4-foot trims from the planing mill and sells bulk loads to small operators that make lawn furniture.

The British Columbia Research Council has developed a process to harden cedar to make a very attractive floor tile or decorative wall panel.

In shingle mills, much residue is used to produce power and heat for operating purposes. However, large amounts are also burned in the burners at considerable expense.

To date only a small percentage of the residue is utilized as by-products. As has already been stated, one company makes briquettes, and this volumewise is the largest use. At this company the material is put through a hammer hog, dried in a three-stage flash drier, and pressed into solid fuel briquettes. This company has further refined the briquettes into charcoal to expand the volume of residues utilized. Another charcoal plant based on sawdust is now in production.

Minor quantities of shingle hay are baled and used for packing nursery stock.

Pulp chips can be made from the spalts and splints, but it has been found that a high percentage of fines and knots develop from this material. The spalts are a potential source of phenolic extractives.

Research into the chemistry of cedar at the Vancouver Laboratory (3) shows that the light-colored heartwood of butt logs contains 10 to 20 percent by weight of water-soluble phenolic extractives that are potentially useful in adhesives, anti-oxidants, drilling muds, and dispersing agents. Their content of pyrocatechol groups suggests investigation of their usefulness in metal cleaning and etching, sequestering agents, and electrolytic refining.

If the chemical extractive of cedar can be marketed commercially, the pulp chips are a logical form from which to extract them. This would have a two-fold benefit, because the extracted chips would then be less corrosive on the digesters. One company has extracted from cedar waste to make an additive for boiler water.

Flakeboard plants that utilize cedar sawmill residues are being planned.

Conclusion

The large volume of western red cedar residues that result from the manufacture of lumber and shingles are deserving of more research into possible uses. At the present time, in addition to the work that is being carried on in the Wood Chemistry Section of the Vancouver Forest Products Laboratory, several of the large integrated companies are engaged in research on cedar. The properties of this wood are such that more uses are certain to be found for it, particularly in the chemical field.

Literature Cited

1. Pogue, H. M. 1958. Continuous forest inventory of British Columbia. Initial phase: 1957. Dept. of Lands and Forests.
2. Annual Report—1957. British Columbia Lumber Manufacturers' Association.
3. Gardner, J. A. F., and G. M. Barton. 1958. The extraneous components of western red cedar. Forest Prod. J. VIII (6): 158.
4. King, F. W., and F. Bender. 1951. Production of insulation fiberboard from western red cedar shingle mill waste. British Columbia Lumberman, Jan.
5. King, F. W., and F. Bender. 1952. Production of hard-pressed fiberboard from western red cedar mill waste. Pulp and Paper Mag. of Canada, May.
6. Dominion Bureau of Statistics.
7. Proceedings of Twelfth Annual Convention of Truck Loggers' Association of British Columbia, Jan., 1955.

Wood Versus Concrete

IN HOUSE FOUNDATIONS

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Crawl-space houses require about 25% more lumber than do the slab type. The trend toward more slabs in the North, traditional basement area for climate reasons, seems to have fallen off.

The construction industry consumes annually about three-fourths of the total lumber output of the United States. Fifty-one percent of the construction lumber is used in new residential construction, 26 percent in new non-residential construction, and 23 percent in maintenance and repair.[2]

Because the construction industry is the major consumer of lumber, the trend in the average volume of wood used to build a dwelling unit is one of the most important indicators of probable future lumber consumption. This trend is influenced by a number of factors such as family income, consumer preferences for building materials and house style, the type of house construction, and price of lumber relative to the prices of competing building materials.

In this article, the foundation characteristics of single-family houses are examined, and suggestions are made as to how changes in material use in foundations affect the wood requirements of the construction industry. Single-family houses account for about 90 percent of all dwelling units currently built in this country.

House Foundations

Three types of house foundations are found in present-day construction: basements, crawl spaces, and concrete slabs. The crawl-space and concrete slab types are both classed as basementless houses. The crawl-space house is built on sills or piers a short distance

[1] Based on a thesis submitted to Harvard University in partial fulfillment of the requirements for a Ph.D. in economics.

[2] Stanford Research Institute. 1954. America's demand for wood.

[3] For purposes of this article, the house foundation includes floor joists, subflooring, and finished flooring found in conventional house

above the ground. The minimum distance established by most building codes is 18 inches. The concrete-slab type has a base of solid concrete partially embedded in the ground. A nonwood floor covering such as asphalt-tile or vinyl-asbestos is usually bonded to the concrete surface. In parts of the South, however, hardwood flooring and carpets are extensively used. In the North, hardwood flooring is favored in some of the expensive slab homes.

There is very little difference in super-structure between basement and crawl-space houses. Both types have sills, stringers, floor joists, subflooring, and usually finished flooring. The main difference between basement and crawl-space houses exists below the ground level, and there wood consumption is insignificant.

The concrete-slab house, however, represents a radical departure from the design of the other two types. It is characterized by the absence of wood from the foundation. The concrete slab takes the place of sills, stringers, floor joists, subflooring, and sometimes the finished flooring found in conventional homes.

Wood Requirements

A change in the proportion of houses built with any of these foundations will be reflected in a change in average wood requirements per house. The nature of this change may be illustrated by comparing the quantity of wood required for the construction of each type of house.

Some of the space in the basement is utilized for certain essential household functions such as laundry and storage. In basementless houses, the space for these household functions is located, as a general rule, in utility rooms on the first floor. These rooms have an area equal to about 15 percent of the gross floor area of the house[4]. Thus a basementless house that is equivalent to a basement house in living space must be about 15 percent larger in terms of floor area above ground. Since the volume of wood consumed in house construction varies (within the probable variation in range of house size) directly with this gross floor area, it can be assumed that a crawl-space house requires, roughly, about 15 percent more wood for its construction than does a basement house.

The slab house differs from the crawl-space house in the absence of wood in the foundation. About 24 percent of the wood in the conventional crawl-space house is used in the foundation. Hence a slab house requires about 24 percent less wood than a

On the basis of these data, houses equivalent in living space, but varying in the type of foundation, will vary in average wood requirements as indicated in Table 1.

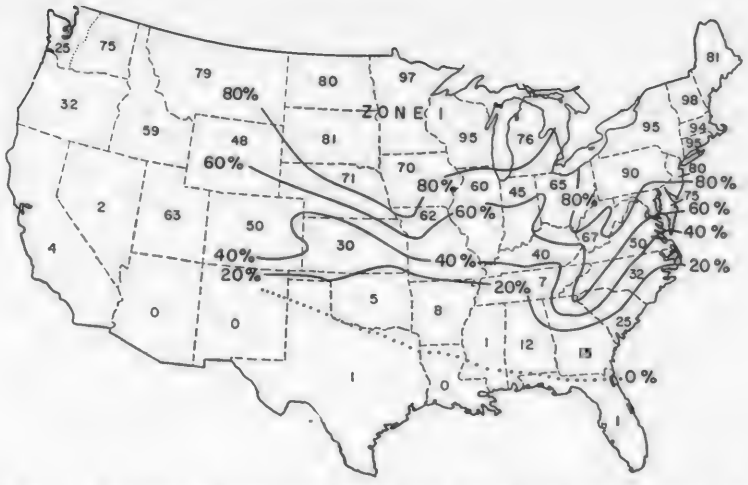

Fig. 1.—Percentage of single-family houses built during 1954 with basements. Zone 1 refers to the northern section of United States within which most houses are built with basements.

Table 1.—INDEX OF WOOD REQUIREMENTS FOR EACH HOUSE TYPE

Type of foundation	Index of wood requirements
Crawl space	115
Basement	100
Slab	87

There will, of course, be some regional variations in this index. But even though only approximate, the index leads to the following conclusions: An increase in the proportion of slab houses and a decline in the proportion of houses with either basements or crawl spaces or both will result in a decrease in average wood requirements per house. An increase in the proportion of crawl-space houses and a decline in the proportion of either of the other two types will result in an increase in average wood requirements per house.

Survey of Foundation Types

In what areas of the United States do we find houses with these foundation types? What are the causes of the geographical differences in types of house foundations used? What has been the trend in the proportion of houses built annually with each foundation? The answers to these questions are fundamental to the understanding of probable future wood requirements by the construction industry.

Although there are no accurate statistics on trends in the proportion of the three foundation types, the proportion of basement houses seems to have declined in recent years, while the proportion of slab houses increased, particularly during the 5-year period immediately after World War II. A recent study by the Department of Labor reveals that, for the United States as a whole, 42 percent of the single-family houses started during the first quarter of 1955 had basements, 39 percent had crawl spaces, 16 percent had concrete slabs, and the foundations of 3 percent were unknown[5]. Comparable data on a state-wide basis are lacking.

To fill the gap in the statistics, a survey of building inspectors was undertaken during 1955. A questionnaire was sent to the building inspectors of all cities with a population (1950 Census) of 6,000 or more. In some of the predominantly rural states such as Kentucky and Mississippi, the mailing list included cities down to a population of 3,000. Questionnaires were sent to approximtaely 2,200 city and, additionally, to 400 township and county building inspectors.

The returns from the survey, after the non-respondents were followed up, was 70 percent. The returns from the cities are given in Table 2 according to population class. The survey covered about 60 percent of all single-family houses built in the United States during 1954.

The building inspectors were asked to give the percentage or number of single-family houses built during 1954 with each foundation type, and to explain the use of foundation types. The percentage of each foundation type in

[4] Zaremba, J. 1958. Some problems in forecasting future wood requirements. Unpublished doctoral thesis, Harvard University.

[5] U.S. Dept. of Labor. July 1956. New housing characteristics in 1955 and earlier years. Monthly Labor Review.

Table 2.—PERCENTAGE OF QUESTIONNAIRE RETURNS FROM THE CITIES

Size of city (1950 Census)	Percentage of cities responding
over 100,000	96
50,000 to 99,000	84
25,000 to 49,000	87
10,000 to 24,000	70
under 10,000	62

new construction in each state is shown on maps of the United States: basements in Fig. 1, crawl spaces in Fig. 2, and concrete slabs in Fig. 3. A resurvey of building inspectors in 1958 reveals no significant change in these patterns.

Survey Findings

The survey findings depict three geographic zones: Zone 1, Northern United States, where basement houses are predominant; Zone 2, Middle United States, where crawl-space houses are most common; and Zone 3, Southern United States, where concrete-slab foundations predominate.

There is general agreement that the decline in the popularity of basements toward the South is associated with an increase in average temperatures. This belief is strongly supported by the fact that the foundation gradient lines in Fig. 1 are approximately parallel to isotherms (Fig. 4).

Furthermore, the comparison of the data of Figs. 1 and 4 shows that basements decline in use mostly in the mean winter temperature range from about 25 to 35 degrees. Notice, first, that the relatively rapid decline in basements from 80 percent to 20 percent in the Great Plains corresponds to a relatively rapid increase in mean winter temperature from about 25 to 35 degrees; the more gradual decline in basements in the North Central area corresponds to a more gradual increase in temperature. Second, in western Washington, where the mean winter temperature is about 40 degrees, the proportion of basements is 25 percent. In eastern Washington, where the mean winter temperature is about 30 degrees, the proportion is 75 percent. Finally, the percentage of basements increases from about 20 percent in eastern Virginia, where the mean winter temperature is about 40 degrees, to almost 80 percent in western Virginia, where the mean winter temperature is about 30 degrees.

The predominance of basements in Zone 1 appears to be due to the economical and effective house heating made possible by this type of foundation. In areas with mean winter temperatures of less than 25 degrees, the space under the floors should be sealed from the cold outside air and kept warm. The plumbing is also protected from freezing.

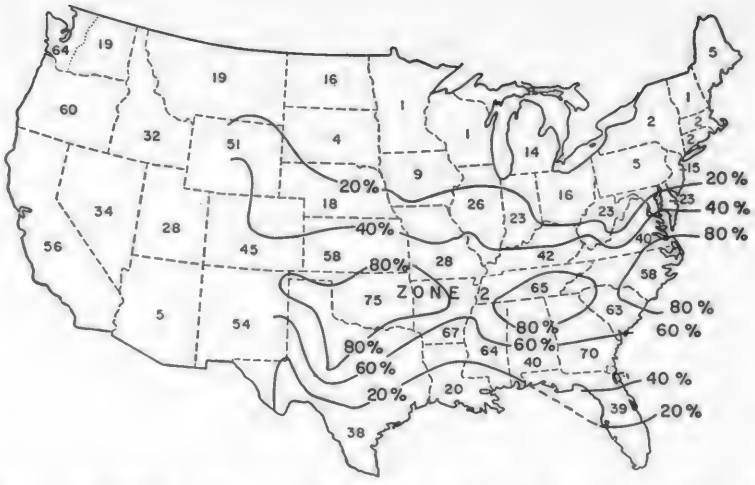

Fig. 2.—Percentage of single-family houses built during 1954 with crawl spaces. Zone 2 refers to an area in the middle south within which most houses have crawl spaces.

Basementless houses in Zone 1 that would maintain heating conditions as effectively as basement houses might thus be more costly. The concrete-slab foundation has met strong consumer resistance in the Northern United States.

The danger of frost-heaving in the north also militates against the use of slabs. The edges of a properly built slab must be set into the ground at least down to the frost line to safeguard the slab against cracking when the earth heaves. Where frost penetrates to a depth of as much as five feet, as it does in the northern prairie states, slab construction would be very expensive.

A comparatively new development in home construction provides evidence of the importance of warm air under the floors in cold weather. In the north-central states, some builders are now marketing a heated crawl space: a vapor barrier is laid over the ground surface to keep the moisture out of the crawl space, closable vents are installed, and the plumbing is not insulated against the winter temperature. Provision is then made for circulating warm air into the crawl space during the winter months. This prevents the plumbing from freezing and keeps the cold air away from the lower floor surface.

In areas with winter temperatures above freezing—characteristic of Zones 2 and 3—effective house heating can be achieved without a basement. Thus, slab and crawl-space construction is encouraged.

There seem to be two reasons for the widespread use of crawl-space houses and the limited use of slab houses in Zone 2. First, cold floors, although they cause less concern here than in Zone 1, are still the most widespread complaint against the concrete slab. Concrete is a good heat conductor, and the moderately cold winters make it somewhat difficult to maintain good heating conditions. Furthermore, water condensation on the concrete inside the house may sometimes create unpleasant problems. The wood floor of the crawl-space house, on the other hand, apparently makes effective heating possible even though the floor is exposed to the outside temperature from below.

The second reason for the popularity of the crawl-space house in Zone 2 is that hardwood floors serve popular tastes and preferences better in cool climates than do asphalt-tile floors. Incidentally, hardwood is more resilient than asphalt tile, and it is generally believed that hardwood floors are less tiring on the feet.

Although hardwood can be installed on concrete, and indeed the technology is highly developed, in Zone 2 this type of construction is not a substitute in the consumer's view; for the conventional wood floor in crawl-space houses.

The heating problem of the slab house could, of course, be met by installing a heated concrete slab. But according to opinions of building inspectors in Zone 2, the cost of a good heated slab is somewhat higher than the cost of a crawl-space foundation.

The popularity of slab houses in Zone 3 is explained largely by three factors. First, in some areas (notably in Texas and California) earth movements occur after dry seasons, and this results in numerous problems for the owner of a crawl-space house. Dur-

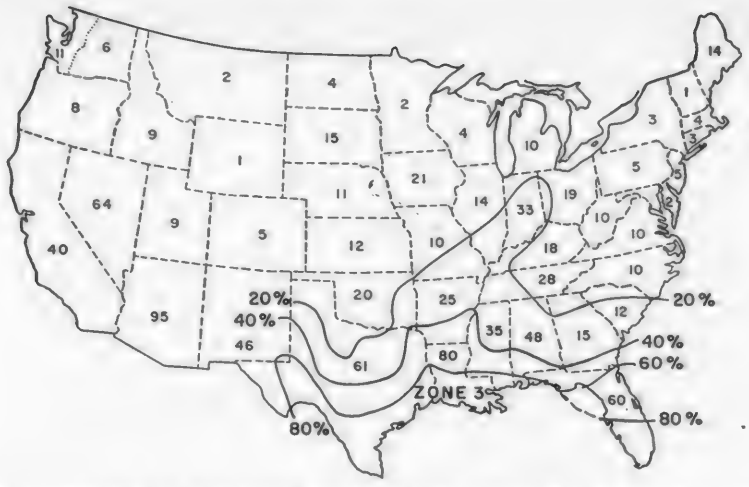

Fig. 3.—Percentage of single-family houses built during 1954 with slab foundations. Zone 3 refers to the far south where most houses have slab foundations.

ing the long dry periods, the soil has a tendency to shrink and crack. When rain comes, the soil around the outside of the house becomes soaked and is capable of exerting an upward pressure, while the soil under the house remains relatively dry. As a result, there is a tendency for the outside foundations of the crawl-space house to be pushed upward while the interior of the house remains relatively unmoved. Cracks then develop in the walls, doors and windows stick, and the baseboard separates from the floor. In the case of the slab house, however, when earth movements occur the entire slab moves —that is, it is said to "float". In such areas, therefore, consumers greatly favor slab foundations over crawl-space foundations.

The second factor is that there is no serious heating problem in the warmer climate of Zone 3. Asphalt tile with its cold feeling and lack of resilience is apparently avoided in many southern areas by the installation of hardwood floors and carpeting on the concrete. Water condensation on the concrete is not a serious problem in warm climates.

The third factor that accounts for the popularity of slab houses in Zone 3 is the danger of termite damage to the wood members of the crawl-space foundation.

It appears, then, that although slab foundations entered the market very strongly after World War II, they have met with marked success only in the extreme south. There, they made their gains largely at the expense of crawl-space houses; the proportion of basement houses seems to have held nearly constant.

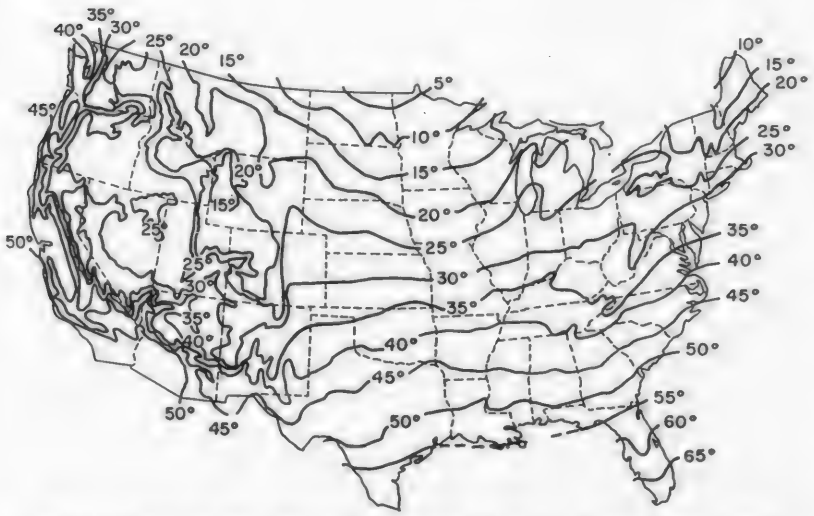

Fig. 4.—Average winter temperature, December to February, inclusive. (From USDA Atlas of American Agriculture, 1936.)

Comparisons with Stanford Study

Are these results in agreement with other studies. One of the more recent studies of demand for wood in residential construction was made by the Stanford Research Institute in 1954. Concerning house foundations, the Institute states:[6]

> ". . . In 1940, about 4 percent of the foundations were of the slab type; in 1950, this type of foundation increased to about 12 percent; and in 1953, about 34 percent of all foundations were of slab construction. Concurrent with the rise of slab construction, full basements have been declining. The percent of dwellings with crawl space has remained about the same since 1920.
>
> "Discussions with large operative builders throughout the country indicated that the trend to slab foundations was largely for the sake of economy . . . With every effort expected to be made to hold down the cost of residential construction . . . it is expected that the trend toward increased use of slabs will continue.
>
> ". . . a summary of builders accounting for 16,595 dwelling unit starts throughout the country in 1953 showed that large operative builders are installing about 80 percent slab floors at the present time. Since about 75 percent of total residential floor space is on the ground floor, it would appear entirely possible that about 60 percent of total residential floor space might be in slabs by 1975."

The findings of the present study suggest that large builders in the far south may well have installed 80 percent slab floors in 1953. It seems questionable, however, that such a percentage could be representative of the whole United States.

There is serious question, also, that consumers generally will switch to slab houses simply because they are cheaper. Apparently, consumers in Zone 1 do not regard the slab house as a satisfactory substitute for the basement house, and those in Zone 2 do not look upon it as an acceptable substitute for the crawl-space house. Perhaps some day builders will develop a type of foundation that is relatively cheap and that meets with favor from consumers in the northern and central latitudes. The slab foundation as presently built, however, is not this development.

Indeed, one wonders if slabs will even hold their own in the future. As noted earlier, 16 percent of the single-family houses built in the first quarter of 1955 had slab foundations, while in 1953, according to the Stanford Research Institute, 34 percent of all houses built were on slabs. These data suggest, if anything, a downward trend.

[6] Stanford Research Institute. 1954. America's demand for wood. p. 98.

Subterranean Termites and Fungi

MUTUALISM OR ENVIRONMENTAL ASSOCIATION [1]

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A laboratory experiment utilizing aerated glass containers, moistened sand, and termites was used to determine the ability of eastern subterranean termites to attack sound, uninfected, southern yellow pine sapwood. Results indicate that previous infection of the wood by fungi is not a prerequisite for termite attack.

Fig. 1.—A photomicrograph of an uninfected radial section from Block 1 (control) unexposed to subterranean termites.

CERTAIN INVESTIGATORS HAVE, in the past, accepted the theory that subterranean termites were able to attack sound, uninfected wood. Recently, however, there has been renewed interest in the belief that before wood becomes susceptible to subterranean termite attack it must previously be infected by fungi.

A number of studies, previously reported (1) have indicated that termites were always associated with various types of fungi. When moist, untreated wood has been exposed and successfully attacked by subterranean termites, the environmental conditions under which it was exposed would also make it susceptible to fungal attack. Thus, in field studies, it would be difficult to determine whether some form of mutualism existed between termites and fungi or whether their association was due only to environmental influences. Studies have shown, however, that termites serve as vectors for fungi by furnishing mobility for the fungal spores.

In the attack of dry, untreated wood by subterranean termites the insects increase the moisture content of the wood to the level that permits fungal infection. The excavated tunnels within the wood are maintained at a high relative humidity by the insect and this, coupled with the increased wood moisture content, furnishes favorable conditions for the germination and subsequent growth of the fungal spores transported by the termites.

Difficulty in a mutualism determination would also be experienced in laboratory studies utilizing wood that had been exposed under normal environmental conditions.

Additional masking factors may also influence termite-fungi evaluations. One factor among these is the presence, in the insects' intestine, of fungal spores and hyphal fragments—previously acquired by ingesting infected wood, and then transmitted to infect the wood used in laboratory tests.

The complexity of the problem dictated that the following study be designed only to delineate the capability of the eastern subterranean termite to attack sound, uninfected, southern yellow pine sapwood under laboratory conditions.

Experimental Procedure

Test material was obtained from an air-dry, all sapwood, southern yellow pine board selected for freedom from visible defects and excessive resin. Sawn 1-inch strips were surfaced 4 sides to ¾-inch square and then severed at 2-inch intervals. Ten blocks were randomly selected for the study; nine were vacuum impregnated with distilled water, and conditioned at 80 degrees F. and 90 percent relative humidity, while one was retained for unexposed control material. The test blocks were placed in aerated 1-pint glass jars (1 block per jar) with sterilized sand containing 20 percent moisture (distilled water).

Subterranean termites [*Reticulitermes virginicus* Banks or *R. flavipes* Kollar] were introduced into the test containers and then the containers were placed in a circulating air, constant temperature and humidity chamber operated at 80 degrees F. and 90 percent relative humidity.

A detailed description of the technique used in collecting and handling the insects and in preparing the test containers has been described elsewhere (2).

Single jars were removed from the chamber after 4,5,6,7,12,14,16,18, and 20 days. The contents of each jar were examined upon removal to ascertain insect vigor and mortality. Test specimens were rinsed in water to remove sand particles and then examined. After inspection they, together with the unexposed control block, were individually severed into 3 approximate cubes, ¾-by ¾-by ⅝inch, and then boiled 4 hours in water for sterilization and softening.

Radial and tangential microtome sections, 18–22 microns thick, were cut

[1] A contributed paper received in December, 1958.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Author: A. E. Lund, a graduate student in the School of Forestry, Duke University, holds a BSF from Colorado State and an MF from Duke. He is a member of FPRS, AWPA, ASTM and Sigma XI, and he received a National Lumber Manufacturers scholarship in 1956 with ten weeks on-the-job training at the TECO research laboratory.

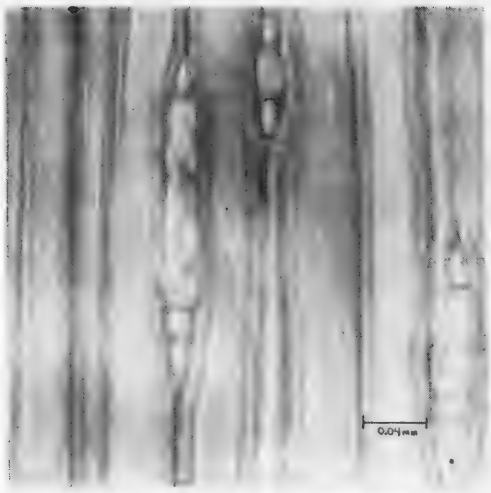


Fig. 2.—An uninfected tangential section from Block 5, exposed to termite attack for seven days.

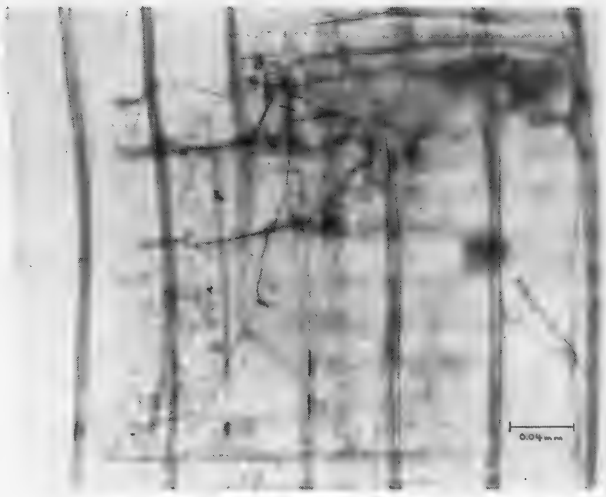


Fig. 3.—An infected radial section from Block 10, exposed to termite attack for 20 days.

from each cube. In the microtoming, care was taken to insure obtaining wood sections from the immediate area of the cube that exhibited evidence of termite attack. The sections were stained with picro aniline blue, dehydrated, and mounted on slides.

A microscopic examination of each slide to detect fungal infection, as evidenced by hyphae, was carried out. Magnifications of up to 970 diameters were used in the inspection.

Results and Discussion

Examination of the contents of the containers after removal from the constant temperature, humidity chamber showed that vigorous, healthy termites were present in each test jar. Mortality, as evidenced by visible dead insects, had not taken place. Each block, regardless of exposure period, exhibited termite attack.

It was noted that within 24 hours after the termites were introduced into the jars they had ingested particles of the pine blocks. This was determined by observations made through the sides of the glass containers.

Examination of the prepared slides demonstrated that the control block, unexposed to subterranean termite attack, was not infected. This was evidenced by the absence of visible hyphae when examined microscopically. The sections obtained from the block which was exposed to insect attack for 4 days were negative when examined for infection. Some slides of the 5,6, and 7-day blocks exhibited one-to-several minute lengths of hyphal strands (stained blue by picro aniline), while other sections from the same blocks were negative. Blocks exposed for from 12 to 20 days were fungus infected. This infection varied from light to heavy, with respect to the magnitude of the stained hyphae within the sections. Table 1 summarizes the data obtained.

Fig. 1 is a photomicrograph of a section removed from Block 1; Fig. 2, a section of Block 5; and Fig. 3 is a photomicrograph of a section of Block 10 exhibiting numerous strands of hyphae.

The results presented should be scrutinized in the light of possible influencing factors. Two of these are: 1. Previous infection of test material. While an inspection of the sections obtained from unexposed material did not indicate the presence of hyphae, it was possible that there was localized infection in areas that were not sectioned. 2. The presence of fungal hyphae may not have been detected in the exposed blocks although they were reported to be free of infection.

From an examination of the data presented in Table 1 it appears that the blocks were, for all practical purposes, free from fungal attack until after 7 days of exposure. However, there are some investigators who feel that it is possible to demonstrate the presence of fungal mycelia in virtually any piece of wood (3). Nevertheless, the termite attack of sound, uninfected wood has been recorded (4), as has the attack of wood that is visually, and to all intents and purposes, sound timber unaffected by fungi (3,5,6).

Summary and Conclusions

Southern yellow pine sapwood blocks, uninfected by fungi, were attacked by eastern subterranean termites within 24 hours after exposure under laboratory conditions. It is concluded from the data presented that subterranean termites are able to attack wood that has not been previously infected by fungi.

These results do not resolve the question of the necessity for the presence of fungi for the prolonged subsistence of subterranean termites.

Literature Cited

1. Hendee, E. C. "The association of termites and fungi" in Termites and Termite Control, pp. 105–116, Univ. of California Press, Berkeley, 1946.
2. Lund, A. E. The relationship of subterranean termite attack to varying retentions of water-borne preservatives. American Wood-Preservers' Association Proc: 44–53, 1958.
3. Gay, F. J. Division of Entomology, C.S.I.R.O., Australia, Personal communication, 1958.
4. Krogh, P.M.D. Department of Forestry, Forest Research Institute, Pretoria West, Union of South Africa. Personal communication, 1958.
5. Lund, A. E. Douglas-fir plywood: its treated and natural resistance to subterranean termites. For. Prod. Jour. 9:220–223, 1959.
   methods. In press, For. Prod. Jour.
6. Pence, R. J. The prolonged maintenance of the western subterranean termite in the laboratory with moisture gradient tubes. Jour. Econ. Ent. 50: 238–240, 1957.

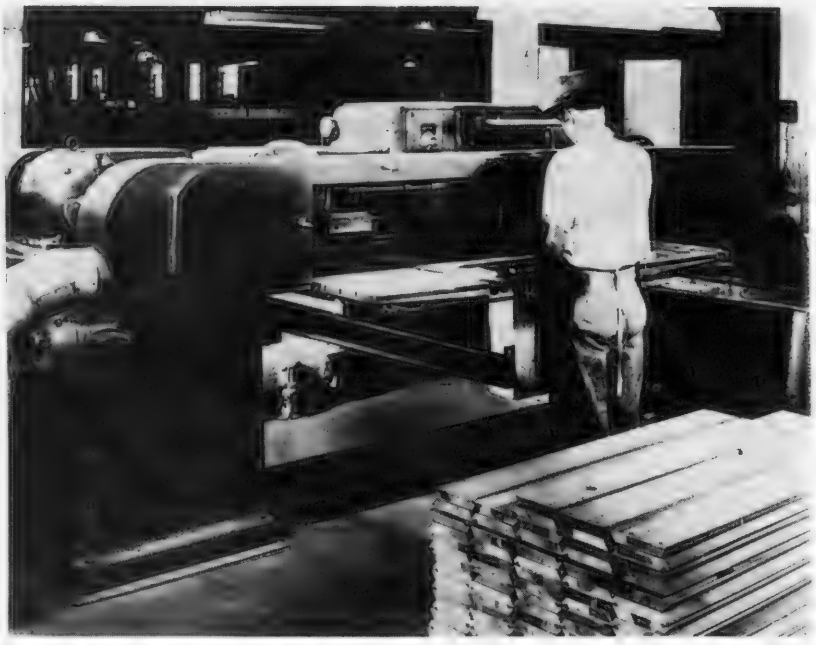
Table 1.—THE PRESENCE OF FUNGAL HYPHAE IN TERMITE ATTACKED BLOCKS AFTER VARYING EXPOSURE PERIODS

Block No.	Termite Species[1]	Exposure to Attack, Days	Number of Slides Examined	Evidence of Fungal Infection, Stained Hyphae
1	--	0	6	Absent
2	V	4	7	Absent
3	F	5	6	Absent–Trace
4	V	6	6	Absent–Trace
5	F	7	6	Absent–Trace
6	F	12	6	Light–Heavy
7	F	14	6	Light–Moderate
8	F	16	6	Light–Moderate
9	V	18	6	Light–Heavy
10	V	20	6	Moderate–Heavy

1. V = *Reticulitermes virgincus*.
   F = *R. flavipes*.

Veneered Stock with Solid Lumber Cores

JOHN E. HYLER
J. E. Hyler and Associates, Peoria, Ill.



Mattison automatic stroke sander in the United Furniture Corporation plant at Lexington, N. C., putting finish on veneered parts with solid lumber cores.

SOLID WOOD CORES FOR VENEERED stock are made by gluing strips together, or they may be built up from short blocks and then referred to as short-block cores. In either case, these cores are not subject to any appreciable degree of warpage after gluing. The grain runs in various directions in different blocks or strips, and so any magnitude of warpage is one direction is offset by warpage in other directions in neighboring blocks or strips.

Strips for solid wood cores are sometimes glued up directly from the ripsaw. Short blocks, not so readily ripped with complete truth, are often processed through a molder or sticker before they are glued together.

Lumber Core Glue-Spreading Variations

Glue spreading core strips or blocks is something of a problem. In a few instances, strips of 1/8-inch veneer salvaged from scrap stock have been interleaved between courses of glue blocks; the veneer strips are first spread on both sides at a single pass so that they function as glue carriers. More often, however, wood strips or blocks are glued together directly.

In an occasional case where large volumes of core blocks are handled, they are processed through a special ripsaw, where they are rough ripped. Subsequently they are processed through a molder or sticker and on emerging from this machine are automatically passed between the rolls of a glue spreader. Special types of conveyors may be used to carry the glue-spread blocks to a layup table. After preliminary arrangement on this table, the blocks are routed into a press, often of electronic type.

Occasionally, where core blocks are glue spread in large volume, a spreader has been provided with auxiliary equipment to keep the blocks moving in well-defined courses. This auxiliary equipment also functions automatically at the gluespreader outfeed to turn the blocks through 90 degrees, so that their glue-spread surfaces are in proper positional relationship for clamping up in the press.

Dressing Glued-up Cores

After cores have been glued in their proper width they must be planed for correct thickness and to provide level surfaces on which veneers may subsequently be laid. All core blocks or strips in a layup should have similar characteristics, particularly in regard to shrinkage. Otherwise, even after they have been preliminarily dressed, there may be enough subsequent shrinkage or swelling in some of the blocks or strips to make the joints appear on the surface of the finished material.

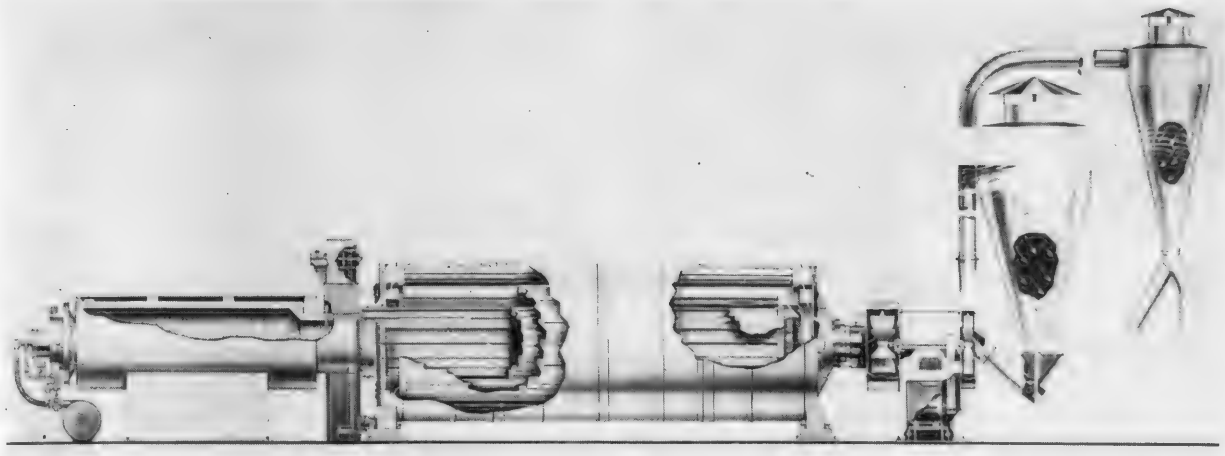
Where one part of a core takes a position even infinitesimally lower or higher than another, light shining obliquely on the finished surface gives it a bad appearance. It is unwise, therefore, to use different species of wood in the same lumber core. It is even more unwise to combine plain-sawn and quarter-sawn material, even of the same species. The shrinkage ratio is always greater tangentially (in reference to the original position of the material in the log) than radially. This means that quarter-sawn material has its greatest shrinkage ratio thickness-wise, while plain-sawn stock shrinks most widthwise.

Especially where lumber cores are relatively wide, the planer should be in the very best of condition so that it will dress the material with perfect truth. Otherwise, in any face veneering operation to follow in the press, any points on the area of cores where they are slightly thicker will receive nearly all the pressure. Any slightly thinner areas will be robbed of most of the pressure they should have.

Lumber cores should always be dressed on a machine having good sharp knives. This is more important than having the surface appear perfectly smooth. Rotary knife marks may be strongly visible on dressed surfaces without causing any particular trouble, but if the knives are dull there is a compressive effect which closes pores and other tiny interstices in the dressed surfaces, so that glue cannot penetrate effectively.

Factors Affecting Sanding Practice

Solid wood cores may or may not be cross-banded before they are face veneered. If heavy face veneers are used, say 1/8-inch thick, cross-banding may often be omitted. If thinner and fancier face veneers are employed, cross-banding should precede laying of face veneers. Where thick veneers are used, material may be drum sanded before it is sent to the automatic stroke or other belt sander. Where face veneers are thin, it is better to do all smoothing at a belt sander. The automatic-stroke machine (illustrated) is perfectly adapted to putting the final sanded finish on applied veneers, whether they have or have not been through a drum sander preliminarily.



Cut-away View of Dryer and Furnace

High Temperature Drying of Chips

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Drying of wood particles such as flakes, shavings, splinters, and chips up to the size of pulp chips can be efficiently accomplished by "High Temperature Drying." This paper gives ways and means by which one gallon of oil dries about 190 pounds of wood from 50 percent M.C. to 6 percent, with little or no degradation of the wood.

THE DRYER most commonly used in high temperature drying is the direct fired, rotary drum type in which the material to be dried is air conveyed through the dryer by flue gases and excess air. The dryer consists of a cylindrical, single pass, refractory lined furnace which is the combustion chamber for the oil or gas fired burners; a three pass cylindrical rotating drum; an exhaust fan which pulls the gases through the furnace and drum; and a cyclone collector to separate the gases and dried material. The hot gases pass directly from the furnace outlet into the center tube of the drum at a velocity, of about 4000 fpm, return toward the furnace through a middle annulus at about 2000 fpm and thence through the peripheral annulus at about 1000 fpm. to the outlet where the velocity again attains about 4000 fpm.

Gas temperatures at the furnace outlet where the wood chips enter the gas stream will reach a maximum of 1800° F. under conditions of 70% moisture content and higher. (All moisture content percentage are expressed on the wet basis; e.g., 70 per cent M.C. means 70 lbs. water per 30 lbs. dry wood.) Normally with wood at 40–50% M.C., the inlet gas temperature will be between 700 and 1200° F. The outlet gas temperature will be 220–250° F. for flakes and shavings and 350–400° F. for pulp chips. In all cases, the moisture content of the particles leaving the dryer is regulated by the outlet temperature of the gases through a regulator which modulates the oil or gas burner.

The principle of flash drying is used in this type of dryer. Light weight particles are air conveyed through the dryer in a matter of a few seconds. Heavy particles will air convey in the high temperature and high velocity channels of the dryer but will begin to drop out of the gas stream as the velocity diminishes. They are then lifted by the flights within the rotating drum and dropped into the gas stream again and again, each time advancing a distance along the drum axis dictated by the particle weight which decreases as drying occurs and gas velocity decreases. The heavy particles may take 5–6 minutes to travel through the dryer.

The easily dried particles pass through the hot gases quickly while those of thicker section and more difficult to dry are subjected to the gradient temperatures for a longer period. Because of this unique method of relating time, temperature and wood mass, the temperature of the dried wood leaving the dryer does not exceed 130–140° F. In this respect, the method could be termed "low temperature drying."

Degradation of the wood does not occur in this type of drying. The drying action occurs at low wood temperatures and the flashing of moisture is so rapid that there is no casehardening of even the larger pulp chips or apparent fiber weakening.

Improper combustion of the fuel oil can produce an oil film on the wood particles. Operation at too high an exit temperature can produce charring of the wood, particularly fine particles that are mixed with large particles. These degrading results are readily apparent and can be rapidly corrected by easy adjustment.

With standard fire controls and safety devices on the furnace there is

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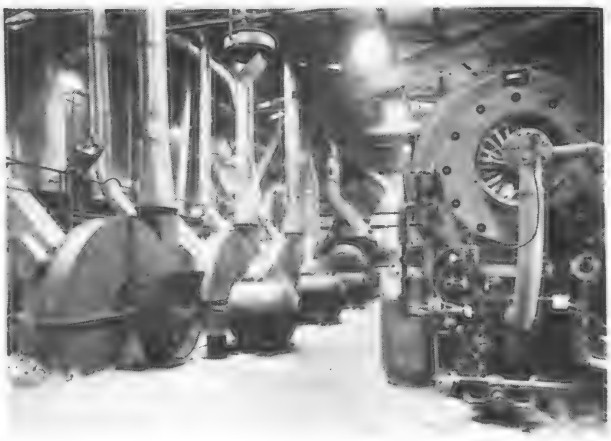
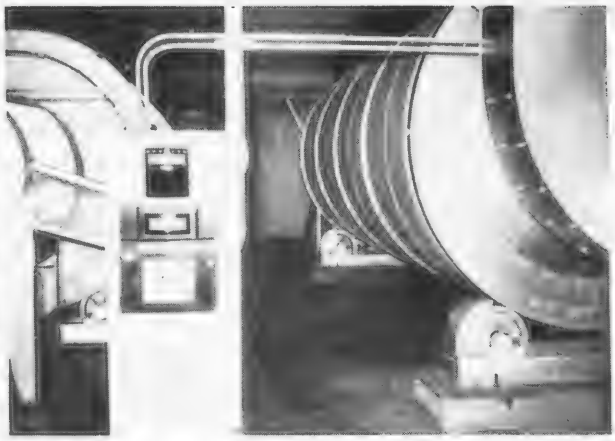
Photographs accompanying this paper are by courtesy of Arnold Dryer Co.

This paper was prepared for presentation at the meeting of the Carolinas–Chesapeake Section of the Forest Products Research Society, Charlotte, North Carolina, November 6–7, 1958.



Furnace Controls and Burner, Gas-oil Combination.



Dual Installation Showing Drums and Temperature Controllers.

little fire hazard. The ignition temperature of wood is a very indeterminate value depending on moisture content, wood mass, temperature of heat source and time subjected to the heat.

For example, wood will char if placed on a hot steam pipe for a long period of time but it also can be placed in a high temperature atmosphere for a short period of time and not char. High temperature drying for a short period of time is the basic principle used in this method of drying which prevents charring and burning.

However, to meet the contingency of human error and mechanical failure, means should always be provided to divert the dried product at the dryer discharge away from the succeeding conveyors to prevent spread of fire or to reject badly degraded wood particles.

The overall thermal efficiency of this drying method is 50–60 percent; i.e., about one-half the theoretical heat content of the fuel is used to evaporate water. The rest of the heat content is used to heat the air, water vapor and wood and to overcome radiation losses. Expressed in other terms: one gallon of oil (150,000 BTU) will dry about 190 lbs. of wood 50 percent M.C. to 6 percent M.C.

Two important factors must be considered when selecting a dryer for a specific duty: 1) Evaporation Rating. 2) Material Handling Capacity.

In most instances, when drying wood particles, the material handling capacity is the limiting and deciding factor which dictates the dryer. size. Since the bulk density of the particles will range from 3–18 lbs./cu. ft. @ 6% M.C., special attention must be given to the air handling system such as fan speed, duct length and air volume. If the dryer can handle the required quantity of dried material, the rate of water evaporation is then checked to make sure that it does not exceed the maximum rate.

It seems obvious that both limitations cannot be exceeded but it is a common inclination to make a selection based on the evaporation rate and ignore the material handling limitation since the latter is peculiar to this type of drying operation. The evaporation rate must not be based on an average moisture content of the green wood but on the maximum moisture content which will be encountered over all seasons of the year. A maximum of 50% M.C. has been found to be a good design estimated for green pulpwood and sawmill waste.

The relation of evaporating capacity and material handling capacity is more clearly shown in Table No. 2 which gives the operating conditions of several installations. Referring to the dryer ratings in Table No. 1, Dryer A is operating at nearly the material handling rating of the dryer (4800 vs. 5000#/hr.), but the evaporation rate of 3960 is well below the 5000#/hr. maximum evaporation rate.

Dryer B and C are drying flakes of low moisture content and consequently have a low evaporation rate and high material handling rates. Dryer C is exceeding the material handling rating (10,200 vs. 7500) by 36%. Particle size and relatively high bulk density have made it possible to exceed the rating. Evaporation, however, is only 37% of rating. Dryers D and E are examples of units operating at only two-thirds of rating by choice rather than by necessity. In each case, however, the next smaller units have an insufficient rating and could not be used.

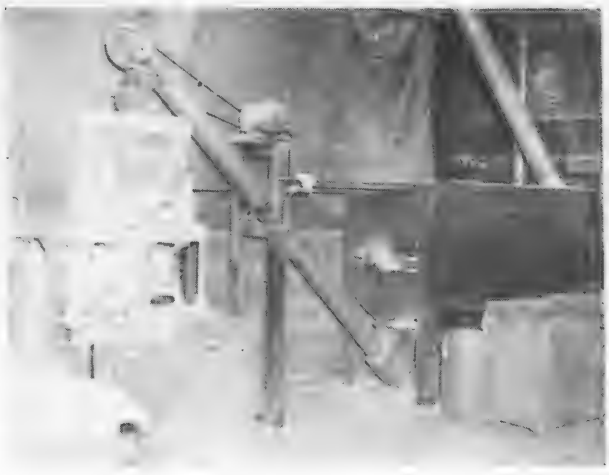
Table No. 1.—TYPICAL DRYER RATINGS

		POUNDS PER HOUR				
		Pulp Chips @ 50% M.C.		Shavings and Flakes @ 50% M.C.		
Dryer Size	Maximum Evaporation Rate—#/Hr.	Water Evap.	Product @ 7% M.C.	Water Evap.	Product @ 7% M.C.
1	2,000	1,820	2,120	1,720	2,000
2	5,000	4,550	5,300	4,300	5,000
3	7,500	6,820	7,950	6,450	7,500
4	15,000	13,640	15,900	12,900	15,000

Table No. 2.—TYPICAL OPERATING DATA

Dryer	Type Wood Particles	Inlet Temp. °F.	Outlet Temp. °F.	% M. C. Wet Product	% M. C. Dry Product
A	Hardwood Flakes	750	230	48	5
B	D. Fir Flakes	700	250	35	6
C	D. Fir Shavings	820	175	26	6
D	Pine Falkes	1120	225	52	5
E	Gum Pulp Chips	800	380	53	7

Dryer	Dryer Size	Dry Product Lbs./Hr.	Fuel	Fuel Pressure psig	Evaporation Rate Lbs./Hr.
A	2	4800	Oil	60	3960
B	2	4250	Oil	55	1900
C	3	10200	Oil	55	2800
D	4	10000	Gas	5	9800
E	2	3440	Oil	50	3260



Granulated Wood Molding

THE INDUSTRY: PAST, PRESENT, FUTURE

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Springfield, Massachusetts

An eleven-year-old industry levels off after rapid expansion. Additional research, new designs, may provide the impetus for another period of growth.

GRANULATED WOOD MOLDING IS basically a process in which refined wood particles are intimately mixed with synthetic resins and the resulting blend molded with heat and pressure to form thermoset shaped articles. The resulting product is different from wood particle board in that it does not involve flat panels, and from plastic molding in that, unlike thermosetting molding compounds, the wood particles retain their identity in the finished piece which may be painted, plastic sheet covered, or molded with pigment incorporated and used as is.

Industry History

Granuplast molding had its inception a little over eleven years ago with its application in the toilet seat producing industry. The cutting and routing of toilet seats from edge glued lumber blanks was wasting a large proportion of wood and involving considerable labor. If the product could be molded from wood particles, less labor would be involved in shaping the seat and less waste would result. The first production granulated wood molded toilet seat appeared in 1945[1] made from coarse chips and liquid resin and was merely a core. The first paintable molding was made in 1947.

With only moderate periodic design changes and a large volume application, production costs proved to be significantly lower than for solid wood seats. Toilet seat producers quickly converted to granulated wood molding, and new seat producers selected the process. Resin suppliers developed resins specifically for this molding, with steady improvements in cure times, efficiencies, and molded physical properties. Wood particle suppliers made available wood flour highly refined as to particle range and moisture content. The molders improved mold design and molding and finishing techniques. Paint suppliers provided surface coating formulations specifically for granulated wood moldings.

These improvements in technology, the production cost advantage over wooden seats, plus the heavy demand for seats during the post-war building boom, caused the rapid initial expansion of granuplast molding. It was only natural that early enthusiasm was high and that other products should make use of this new material. Some of these products have been successful, others proved to be misapplications, while others could not compete with still newer materials.

Among these earlier applications, some of which have stood the test of time, are bowling and croquet balls, shuffleboard discs, shoe heels, instrument bases, dishes and salad bowls, lazy susans, furniture components, paper roll plugs, hamper tops, brush backs, toys and casket tops. Although none of these applications approached toilet seats in volume, they added to the initial expansion of granulated wood molding.

Reference to Table 2 will show that toilet seats are still the dominant product using wood molding, followed by furniture components. All other products combined only slightly exceed the volume application of the second most important product. The factors causing the recent leveling off in the granuplast industry expansion can therefore be explained in terms of seats and furniture components.

The conversion from solid wooden to granulated wood toilet seats has proceeded to completion and only a very few solid wooden seats are still produced. The contribution made to the industry's growth by this conversion has been completed. This fact and

[1] Midyette, A. L. 1957. Wood particle molding. J. For. Prod. Res. Soc. 7 (1): 1–6

A contributed paper (May, 1958) presented at the Nt. Northeast, Ea. Can., and ASME Meeting at Syracuse, March 30—Apr. 1, 1958.

Table 1.—GRANULATED WOOD RESIN CONSUMPTION BY RESIN TYPE, 1957

Resin	Percentage of Total Resin Consumption
Phenolic	76.6
Melamine	12.8
Urea	0.9
Miscellaneous[1]	9.7
	100.0

[1]Includes melamine-urea, liquid urea (solids basis) and amino phenolic.

the recent decrease in new home starts, softening the demand for toilet seats, are two major reasons for the present near-level growth rate in the granulated wood molding industry.

Furniture components such as chair backs and seats and school desk tops have been molded for over two years and are becoming increasingly important. However, because of the relatively low flow properties of granuplast blends, the more complex the part geometry the more difficult the molding problem, and only a few molders have solved the problems with respect to furniture components.

Acceptance by the furniture industry has been slow. Wood has been traditionally used for many years and is particularly well suited to situations where style changes. Mold amortization must be faced, however, and is successfully being handled, as it must be, since low cost tooling for molding cannot be forseen.

All the other current granulated wood applications listed in Table 2 appear to have reached their maximum usage and have little overall affect on the industry.

Present Status

There are currently 30 granulated wood molders in the United States, two in Canada, and one in South America. The United States producers in 1957 consumed about 45 million pounds of wood or the equivalent of approximately 17 million board feet of lumber; slightly over half being softwoods with the remainder mostly birch and maple. Powdered resins are largely used because of the fine mesh wood particles employed in the process. The types of resins employed (Table 1) include phenolic, melamine, urea powder, urea liquid, melamine-ureas, and amino modified phenolics.

The granulated wood molding industry is not highly integrated; molders purchase their wood flour and resins in bulk and employ manufacturers' representatives to sell their products. Only six of the 30 molders manufacture their own wood flour and of these six only one controls the process from wood scrap supply to consumer sales. The products produced from granuplast in 1957 and the relative importance of each according to their portion of the total resin consumed are shown in Table 2.

What are the physical characteristics of this material which last year consumed 45 million pounds of wood? Variables such as resin type and content, wood species, particle size and shape, molded specific gravity etc., combine in each plant to yield end product properties which are not exact for all applications. Specific gravities from 0.7 to 1.3 and resin contents from 5 percent to 50 percent create a range of physical properties so that it is of greater value to cite a few specific examples.

The physical properties of two production and one experimental molding are listed in Table 3 as well as comparable properties for maple lumber and general purpose phenolic molding compound. It may be seen that the moldings can be tailor-made through specific gravity and resin content to be superior to wood in most properties except weight and strength of wood along the grain. It is interesting to note that granuplast molding consumes more wood than the wooden product it displaces, by having a higher specific gravity.

Advantages

Granulated wood molding has demonstrated advantages which, if properly exploited, will lead to new applications. One of these advantages is low cost. The raw material costs of a molded cubic foot of granuplast, 15 percent phenolic resin and 0.9 specific gravity will be about $3.40 or approximately equal to the price of a cubic foot of rough birch lumber. Therefore when compared with wood articles, the economic advantage will be based on reduced labor costs to produce a given part. If over 25 percent of the wood has to be cut away in woodworking, molding will be lower in cost than for the solid wood product.

A number of general purpose phenolic molding compound applications using granulated wood have shown lower end product costs. While the raw material costs of a molded cubic foot of granulated wood are about $3.40, they are about $19.00 when a general purpose phenolic molding compound is employed. It must be recognized, however, that cure cycles

TABLE II.—GRANUPLAST RESIN CONSUMPTION BY PRODUCT TYPE

Product	Percentage of Total Resin Consumption
Toilet Seats	73.0
Furniture Components	13.0
Dishes	4.8
Croquet Balls	3.4
Lazy Susans	3.1
Bowling Balls	1.7
Paper Roll Plugs	0.5
Shuffleboard Discs	0.3
Toys	0.2
	100.0

are longer and physical properties are less favorable.

A second advantage in comparison with wood is a considerable reduction in waste. A third advantage is that certain physical properties such as hardness and dimensional stability are improved although the beauty of wood's grain is lost. Advantages of pigmented melamine granulated wood moldings over plastic laminates include a molded rather than a banded edge, greater color depth, and superior durability. Nicks and scratches are easily buffed from melamine moldings.

Future Outlook

In the future we may expect increased usage in the furniture industry, particularly in institutional furniture where volume is high in constant design parts. New applications will appear when research on molding techniques makes possible a greater variety of shapes and designs. Data is needed on physical properties beyond those required for toilet seats and on molding characteristics and physical properties at specific gravities in the range of phenolic molding compounds.

Summary

The technology of granulated wood molding, including resins, wood particles, and molding techniques, has steadily improved. Applications have demonstrated economy and quality in diverse product areas. In general, existing product areas have been well exploited and new applications are needed for further expansion of the industry. Further improved technology will make it possible to employ the advantages offered by granuplast in new products which will cause a resumption of the last decade's growth.

Table 3.—PHYSICAL PROPERTIES OF TWO GRANULATED WOOD MOLDINGS, SOLID WOOD, AND GENERAL PURPOSE PHENOLIC MOLDING COMPOUNDS

	Specific Gravity	Modulus of Rupture	24 Hour H_2O Absorpt	Hardness Rockwell "M"	Screw Pull
Molding A	0.90	3300 psi	6.0%	80	350 lbs.
Molding B	1.17	7000 psi	8.2%	95	---
Molding C	1.05	7500 psi	3.5%	110	600 lbs.
Hard Maple	0.68	15800 psi	19.4%	Too Soft to Measure	473 lbs.
Molding Compound	1.32–1.45	8500–12000 psi	0.3–1.0%	110–120	

Molding A—Toilet Seat Cover. Molding B—Lazy Susan. Molding C—Experimental Molding with Resin Rich Surface. Molding compound values and specific gravity and flexural strength of hard maple; values as published. All other values taken from laboratory data.

WORLD-WIDE
Forest Products News

FAO Conference on Wood Technology

L. J. Markwardt
Chairman of the U. S. Delegation
FAO Conference on Wood Technology
Madrid, Spain

The FAO Conference on Wood Technology is One of the Effective Units Involved in Interchange of Technical Information, Encouragement of Technical Assistance, and Unification of Research Practises to Help Achieve World-Wide Comparability of Research Results and Findings

ALTHOUGH THERE IS A POSTWAR organization that has been taking an increasing role of leadership in worldwide forestry and forest products activities, relatively little has been published in the United States about its program of work. This is the Food and Agriculture Organization of the United Nations, which now has a membership of some 78 countries. It is interesting to note that forestry is thus recognized in this unit as a basic part of agriculture, and that forest products are recognized as a basic part of forestry on a worldwide basis.

The Forestry and Forest Products Branch of the Food and Agriculture Organization of the United Nations has organized two technical panels in the field of forest products—one dealing with wood chemistry and the other with wood technology. The function of the FAO Conference on Wood Technology is concerned broadly with the problem of making our forest supplies go further and serve mankind better. The program includes among member nations the interchange of technical information and research findings, the unification as far as practicable of research methods, and the development of improved practices that lead to improved and more efficient conversion and utilization of the forest crop.

In the 12 years since the Conference on Wood Technology was organized, there have been five international meetings. The technical work of the Conference is handled by eight working parties, which represent different areas of subject matter in the forest products field. Through the various meetings much has been accomplished in the exchange of information and unification of test methods. The last FAO Conference on Wood Technology was held at Madrid, Spain, in 1958 with 59 delegates from 31 countries in attendance. Attendance from the United States included Alan D. Freas, Assistant Director of the Forest Products Laboratory, as a delegate and Professor F. F. Wangaard, Yale University, as observer.

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The principal accomplishments and progress are achieved through review and discussion of the results of interim studies and reports of the eight standing working parties of the conference. The following is a brief review of the subject matter covered and actions taken at the Madrid meeting.

Testing Methods for Working Party on Fiberboard and Particle Board: Five test procedures for evaluating the physical and mechanical properties of fiberboard and particle board were approved: the hardness test, including the Janka ball test method, the Monnin test method, and the steel ball test method; the nailhead pullthrough test; compression perpendicular to faces and recovery test; dimensional stability under different relative humidity exposures; and durability tests of fiberboard for interior use. FAO has now an approved series of some fifteen physical and mechanical tests for fiberboard and particle board. These are in most details similar to those adopted by the American Society for Testing Materials. Detailed procedures were presented for 10 additional tests, ranging from screw withdrawal to abrasion resistance.

At a preliminary meeting differences in end uses of fiberboards and particle boards were brought out, and from this the necessity for some differences in testing methods. The Conference agreed the Working Party should be divided into two sub groups, one on fiberboards and the other on particle board.

Working Party on Testing of Mechanical Properties of Timber

Selection of Test Material: The Conference reaffirmed the importance of selection of test material for the evaluation of physical and mechanical properties, with particular consideration to taking the fullest advantages of modern concepts of recognized statistical methods. The Conference recommended that information on available sampling techniques and detailed procedures for sampling be collected and reported for study at the next Conference.

Conditioning and Seasoning: The Conference reaffirmed the previous agreements regarding conditioning of test specimens. Recommendations with respect to seasoning provide for conditioning to as nearly 12 percent moisture content as possible without defining the specific procedure for accomplishing this.

Shear Parallel to Grain, Torsion and Modulus of Rigidity: Although shear test methods have been under study for many years there is still a need for a simple and effective test providing reliable shear test results free from influences of significant stress concentrations.

It has long been recognized that the notched shear specimen now employed in some standards has undesirable stress concentration. However, a report presented to the Conference giving results of tests comparing the standard block shear test method and the more

accurate panel shear test method showed a remarkable agreement in shear strength values obtained by the two procedures.

It was agreed that torsion test methods should be included for the evaluation of shear strength and modulus of rigidity. The plate shear test method as described for plywood can also be satisfactorily employed for timber. Where necessary the appropriate size of specimen can be obtained by edge-gluing.

Tension Perpendicular to Grain: While detailed requirements for large size tension perpendicular to grain specimens have already been established at a number of laboratories, there remains the problem of developing a simple specimen without stress concentrations that can be fabricated from material of the smaller cross sections employed for standard strength studies.

Compression Perpendicular to Grain: Considerable discussion was given to compression perpendicular to grain tests. It was recommended that the Working Party prepare test procedures for a compression perpendicular to grain test employing a cube or rectangular specimen in which the load is applied to the entire surface. Consideration should also be given to the so-called "stamp" test in which the load is applied only to a central portion of the surface of the test specimen.

Impact Bending: Recommendations of previous conferences were noted with respect to certain impact bending methods, namely the Monnin and the toughness machine pendulum tests and the vertical drop (Hatt–Turner) test. The results of extensive tests to compare the Monnin impact and the toughness test method were presented.

Hardness: In addition to the extensively used Janka and Monnin methods a number of other procedures have been suggested: the falling ball test, a method using a cone, and others. The Conference recommended that correlation of different methods be undertaken and reported at the next Conference.

Abrasion Test Methods: Recommendations for possible standardization of abrasion tests are required. Exchange of information will be of value for those laboratories interested in the abrasion properties of wood.

Structural Problems: The Conference recognized that prominence should be given to structural problems. Among such urgent problems are test Among tuch urgent problems are tests of timber in structural sizes and long term loading effects on timber.

Working Party on Testing Methods for Veneer, Plywood and Other Glued Veneer Constructions

Most of the comments and recommendations concerning Testing Methods for Veneer, Plywood and Other Glued Veneer Constructions relate to modifications or refinements of the major tests agreed upon by the Third Conference.

Static Bending: Provisions of the specifications as regards static bending tests could be improved with respect to span-depth ratio and rate of loading requirements. Agreement was reached on the modification to part of the relevant clause (5.1 page 83 of the Third Conference Report) in the specification as follows:

"The span shall be 48 times the net thickness of the plywood as measured between the outer fibres of the external veneers having their grain parallel to the span. For plywood tested perpendicular to the grain the net thickness shall be equal to the total thickness less the combined thickness of the face veneers."

Hardness: The hardness penetration test was recognized by the Conference as a valuable method for evaluating the hardness of improved woods and other veneer constructions of very high density. Before recommending its adoption, however, as an additional or alternative test for these materials, it was agreed that further study should be made, particularly with respect to the relative merits of the ball and cylinder methods.

Panel Shear: The methods specified for measuring panel shear and their limitations as regards the measurement of the modulus of rigidity were discussed.

Plywood Glue Shear: Various suggestions were put forward concerning the plywood glue shear test. Recommendations for the provisions of correction factors for both core thickness of 3-ply construction and for speed of testing were examined by the Conference. It was agreed that no change should be made; these recommendations should, however, be studied. The "knife test" as an additional test method for this property should be examined.

Application of Test Data to Structural Plywood and the Derivation of Design Stresses: Considerable discussion took place on this special item concerning application of test data to the derivation of design stresses. This problem is of greatest importance and extremely complex. The Working Party is to continue its study and obtain as far as possible all existing data and information on the application of the test data to design, and report its progress to the next conference.

Working Party on Structural Grading

Strength Data: The Third FAO Conference on Wood Technology recommended the consideration of a series of preferred numbers for strength and stress levels, preferably geometric. Such a series was presented to the Conference for consideration. The Conference recommended the use of the series of strength and stress levels presented.

Factors Affecting Strength: The principles of structural grading involve a knowledge of the effect of natural characteristics and of various defects on strength and the interpretation in terms of actual structural timber strength or grade strength ratios. Such characteristics are, for example, knots, cross grain and checks. It was recommended that further studies be made on their influence on strength properties to permit as far as practicable a closer grading for strength, thus permitting higher strength and a more uniform quality within a grade.

Control Tests: In some countries the rules of structural grading systems are applied in establishing the acceptable quality for design without further testing. However, in others and between countries, control tests are required from time to time to check the quality as established for the minimum requirements on the grade. For this purpose, methods of conducting tests of structural timber are required.

Grading Rules and Their Relation to End Use and Size of Timber: The best utilization of timber for strength uses can be obtained by establishing special grades for the various typical uses. It is thus possible to select timbers especially high in bending strength for beams; high in compression strength for posts; and with high tensile and compression strength for other structural elements. However, it is obvious that such grading for specific end uses increases the complexity of structural grading.

Future Activities of the Working Party: In considering further improvement in structural grading, the Working Party should continue its study of:

1) The effect of knots and cross grain and other characteristics on strength

2) The unification, as far as possible, of methods of measuring such characteristics and interpreting them in terms of their effect on strength

3) The development of non-destructive methods and techniques for more accurate appraisal of the inherent strength of structural wood so that

each piece of timber can be classified and used as near as possible its full potential design level

4) The unification as far as possible of methods of testing structural timbers

5) The interpretation of ultimate strength in terms of statistical factors, and where applicable, the development of basic stresses, considering pertinent factors such as load requirements, duration of stress and factor of safety

6) Information on structural timber practice should be collected and presented to the next conference

Working Party on Sawing and Machining

In recent years the ever-increasing value of timber has made it mandatory to effect savings in conversion costs and to reduce waste in the sawing and machining operations. Considerable changes have already been effected as a result of research, and the Conference noted the continued emphasis being placed on this subject by laboratories working in this field.

Laboratories presently working with some type of pendulum dynamometer in sawing studies were encouraged by the Conference to join in a cooperative research study aimed at ascertaining the differences, if any, which exist between the various dynamometer devices now in use.

The Working Party plans to continue the study of the methods for evaluating machinability of wood. Laboratories equipped to work on this field were urged to coordinate their efforts to attain a uniform system for this purpose. In this connection the U.S.F.P.L. Report No. 2108, "Development of Methods for Evaluating the Machining Qualities of Wood and Wood-Base Materials," which has now been adopted as a new ASTM Standard was recommended for study.

The results of the survey on the sawing and machining of different woods reported by the Swedish F.P.L. revealed a wide range of cutting practices, even on the same species of wood. This is undoubtedly due in part to the large number of factors that influence the quality of cutting.

Fire Test Methods

Because of the importance of fire ratings with respect to the use of certain forest products, such as fiberboards, the FAO has established a special Working Party on Fire Test Methods for Wood and Wood-Base Materials. This Working Party would review the availability and features of different test methods with the object of obtaining improved recognition for certain of the most promising procedures.

Included with the reports furnished the Conference was FPL Report No. 2097, "Small Tunnel Fire Test for Measuring Surface Flammability," by Bruce and Miniutti.

Specialists from fire research organizations in Europe were invited to present papers. The Conference recommended close cooperation with other international organizations working in the field of fire testing. It was agreed that it was premature to consider the formulation of an international standard test for reaction to fire.

Working Party on Physical Properties of Wood and Wood-Base Materials

The Working Party on Physical Properties is relatively new, and no specific methods have yet been prepared for consideration. The scope of work includes sorption, shrinking and swelling, thermal conductivity and diffusivity, dielectric properties, rheology, and seasoning. A bibliography of literature concerning physical properties of wood and their testing methods is to be made as a basis for developing specific procedures.

Working Party on Classification of Wood-Base Materials

The Working Party on Classification of Wood-Base Materials is relatively new and has as yet not developed any procedures. One of the German standards deals with a classification, employing numerical symbols based on a decimal system of classification with numbers for the wood materials, the binding agents, chemical additives, preservatives, and wood species. The discussion brought out some serious difficulties and reservations, such as the problem of keeping the classification up to date, the use of complex binding agents, and differences in nomenclature.

Other Subjects

International Association of Wood Technologists: Attention was called to the problem confronting each organization of keeping abreast of research programs of other laboratories working in the field of forest products, the increasing difficulty of obtaining current information on results obtained at different sources, and the problem of keeping up to date on an international basis on the large and expanding volume of literature. Even the best organized laboratories and documentation centers may thus pass over sources of valuable information, with the result that researchers risk wasting time on experiments that are a duplication of time and effort.

To meet these problems an International Association of Forest Products Research Laboratories and Documentation Centers, under the sponsorship of FAO, has been proposed.

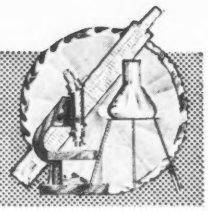
At the Madrid Conference a special meeting of the Working Party chairmen was convened to discuss the possibilities of developing an organization to some extent paralleling the purpose and functions of the Forest Products Research Society. The purpose in general would be the exchange of information and the encouragement and promotion, though not the supervision, of research. In scope the subject matforest products, from logging to end use.

With respect to finances, various possibilities were considered. It was generally agreed that membership fees and income from publicity and services would provide the best basis of financial support. It was estimated that a minimum budget of $20,000 to $30,000 would be required to inaugurate the organization. In considering various types of membership, it was agreed that qualifications should not be too restrictive. Three possible categories mentioned were active members, associate members, and sustaining members.

Mr. Glesinger indicated that he was prepared to recommend to the Director-General of FAO that sufficient funds be set aside to underwrite the cost of an executive secretary for a limited time pending the formal organization. It was voted to establish a steering committee of 10 or 12, with the thought that it would meet at some future date to work out and develop complete plans for the new Society.

Overall Appraisal: Very substantial progress has been made in the international interchange of technical material, and in international agreements on methods of testing wood and wood-base materials and products of various kinds to evaluate their properties. Through active participation it is possible to bring to the Conference the background of the extensive results and experience of the Laboratory, including methods of test, improved practices, and research procedures, and through this effort obtain international review and consideration of these viewpoints and practices. At the same time the Conferences have afforded an opportunity to benefit from the extensive experience and results of others in the same field.

Abstracting the Literature



WOOD—STORING AND HANDLING

Lehela, Eero. Sorting and storing of saw logs. Paperi ja Puu 41, no. 3: 101-5, 107-9 (March, 1959. [In Finnish; English summary]

Various methods, machine equipment, and economic features of sorting, storing, loading, and handling logs are described, together with their advantages (manpower savings, independence of weather conditions, higher bark-fuel value, faster inspection and delivery, and reduced sinkage losses). 2 tables and 14 figures.

Wibstad, Kjell. Wood transport from forest to mill. Norsk Skogind. 13, no. 3: 71-7 March, 1959). [In Norwegian; English summary]

The annual transport of logs and pulpwood in Norway is approx. 525 million tons/km. and represents 25% of all road transport. Waterways account for 70%, railways for 20%, and trucks for 10% of the wood transport, the first two being most important for long-distance and the last for short-distance hauling. Roughly 50% of the annual lumber output in Norway is transported by trucks, usually equipped with trailer and winch or crane. The Norwegian railroads have constructed cranes of 15-ton capacity in centrally located stations about 30 km. apart for convenient reloading from truck to freight car. The average ciculation time of pulpwood in Norway is 1.5-2.0 yr., efforts being made to shorten this time interval. 1 table and 5 figures.

WOOD WASTE

Muller, Werner L. Design of a wood-powder plant. Holz Roh- u. Werkstoff 17, no. 3: 102-14 (March, 1959). [In German; English summary]

Since woodmeal or wood powder finds widespread application as a filler and pigment extender for molded plastics, the author presents plans for the design of a wood-powder plant with a production capacity of 85000 annual tons of wood powder (from sawdust and planer shavings) in three work shifts, along with economic, power, and technical operating data. 1 table, 16 figures, and 4 references.

PARTICLE BOARD

Klauditz, Wilhelm. Scientific, technical, and economic principles of wood-particle board manufacture. Kunststoffe 49, no. 4: 158–65 (April, 1959). [In German]

The flat-press method and the extrusion-press method (continuous Kreibaum process) of molding wood-particle boards are reviewed, and the history, development, and present economic status of the German particle-board industry are outlined. 2 tables, 12 figures, and 30 references.

BARK

Marian, J. E., and Wissing, A. The utilization of bark. Part 3. The utilization of polyphenols in spruce bark extractives in adhesives. Svensk Papperstidn. 62, no. 6: 187–93 (March 31, 1959). [In English; Swedish and German summaries]

The reactivity of spruce-bark tannins to formaldehyde has been determined as a function of the formaldehyde/polyphenol ratio and of the extract pH. The extractives have been tried as ingredients of a phenol-tannin-formaldehyde resin glue setting at 110° C. Commercial spruce-bark extract proved to be less satisfactory than an extract enriched in reactive polyphenols which gave a plywood adhesive of good dry strength, although of low resistance to boiling water. 7 tables, 2 figures, and 20 references.

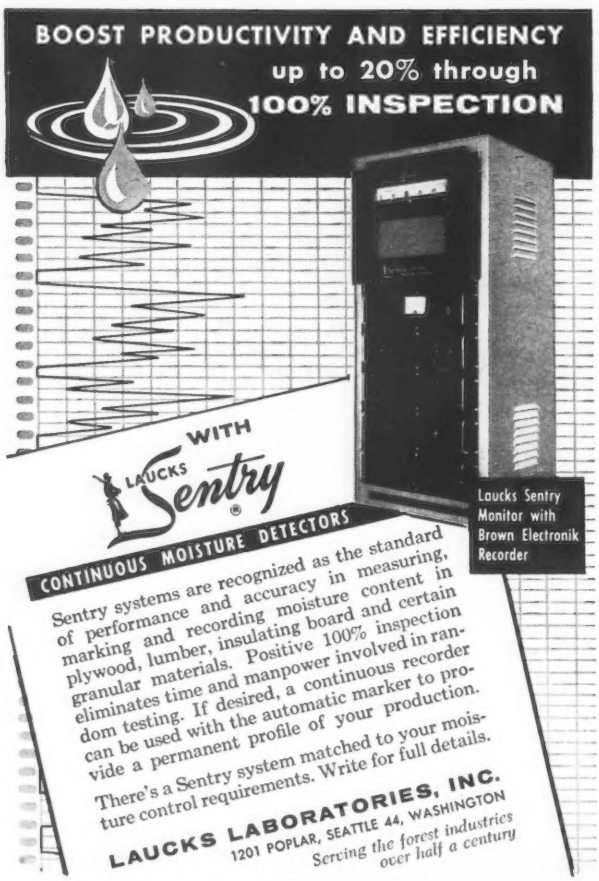
Marian, J. E., and Wissing, A. The utilization of bark. Part 4. Fibres from spruce bark in wet process hardboard. Svensk Papperstidn. 62, no. 7: 225-9 (April 15, 1959). [In English; Swedish and German summaries]

Separate fiberization of spruce bark (under conditions milder than for conventional sprucewood defibration) and admixture of the fiberized bark into a normal spruce wood furnish in amounts up to 40% (30% if a heat treatment followed) produced hardboards with equaled bark-free hardboards in bending modulus of rupture, water absorption, and thickness swelling. The present use of unbarked wood in the wallboard industry saves the mills a debarking operation and eliminates the accumulation of bark waste at the plant site. The separate mild pulping of bark, however, would permit the addition of bark quantities greatly in excess of the natural bark: wood ratio (about 1:9) and thus would considerably enlarge the raw-material supply of the hardboard industry, apart from contributing to the solution of the universal bark-disposal problem. 2 tables, 4 figures, and 35 references.

BARKERS AND BARKING

Christiansen, Neils B., and Fedkiw, John, Chemical debarking—is it economically advantageous? Syracuse, N.Y., State University College of Forestry at Syracuse University, 1959. 28 p.

Based on replies from 17 pulp and papers mills in the New York, Pennsylvania, and New England area, the relative merits of chemical barking (with sodium arsenite) vs. drum barking and sap peeling have been compared, taking into account five cost factors—barking costs, transportation and handling costs, cost of purchased wood, forest-ownership costs, and capital requirements of each system. A comparative analysis of these factors indicated that drum barking is ordinarily the most economical method of bark removal from pulpwood, and that chemical barking and sap peeling may be economical only under special circumstances.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chemical barking may be a valuable adjunct where wood requirements are slightly higher than the capacity of a drum installation but not high enough to justify the addition of another drum. Moreover, it may be useful for small, geographically removed, or otherwise different operations not suited for the production of either rough- or sap-peeled wood. 14 tables, 6 figures, and 9 references.

PAPER AND BOARD, BUILDING

Liiri, Osmo. Manufacture of hardboard by the dry and semidry processes. I and II. Paperi ja Puu 41, no. 3: 85-90, 92-6; no. 4a: 147-58 (March and Special issue, April, 1959). [In Finnish; English summary]

The first part deals with the physical and chemical changes of the fibrous material during hardboard manufacture, particularly during air-felting and pressing, and with the advantages and disadvantages of dry and semidry processes. The second part describes experiments on process variables affecting the manufacture of air-felted hardboard from Finnish pine and birchwood fiberized in defibrators and Bauer refiners, as well as from dry planer shavings fiberized in a Pallmann mill. The most suitable conditions were found to be a temperature of 190° C.; a pressure of 60 kg./sq. cm. for 1.5 min. in the first and of 10 kg./sq. in the second stage for 7 and 8 min. by the dry and semidry process, respectively; and a mat moisture content of less than 10% for the dry (S2S) and 30% or more for the semidry (S1S) process. At least under laboratory conditions, the semidry process causes more troubles than the dry process, particularly because of fiber clusters and uneven moisture distribution. In most cases, a resin content of 1.5% suffices. A wax content of 1.0-1.5% retards water absorption but also reduces the strength of hardboards. Fiber dimensions exert a great influence on the properties of air-felted hardboard; screening to remove coarse fibers and fines improves the properties. Birch produces a somewhat stronger but more water-absorbing board than does pine. Applying a surface layer of fines improves the appearance but decreases the strength of the board. Spraying the mat surface with water slightly improves both the strength and the smoothness of boards. Heat-treatment decreases the water absorption somewhat without affecting the strength of board.

Watson, A. J. Pulping investigations. Influence of wood storage on pulping and papermaking properties. Proc. Australian Pulp and Paper Ind. Co-operative Research Conf. 16: 86–90; discussion: 91 (1957).

Kraft pulps were prepared from freshly cut *Pinus radiata* and from samples which had been stored for varying lengths of time under various conditions (e.g., for 3 months under water or air-dried, with or without subsequent oven drying or soaking, etc.). Similar but more limited studies were conducted on samples of *Eucalyptus regnans*, and the strength properties of all the pulps were evaluated and correlated with type of storage. The results obtained indicate that it is best to pulp *P. radiata* in the green condition, whereas underwater storage appears to be the least desirable procedure. Storage of the wood has its most adverse effects on those properties associated with fiber bonding. *E. regnans* showed no marked differences between the green and the airdry wood when pulped with 15% total alkali, but at higher alkali concentrations the airdry wood gave a pulp that was inferior in all strength properties.

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CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL, published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England.

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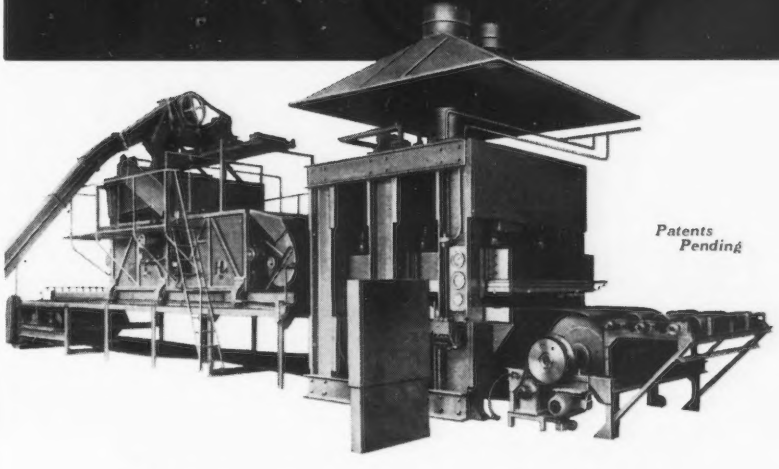

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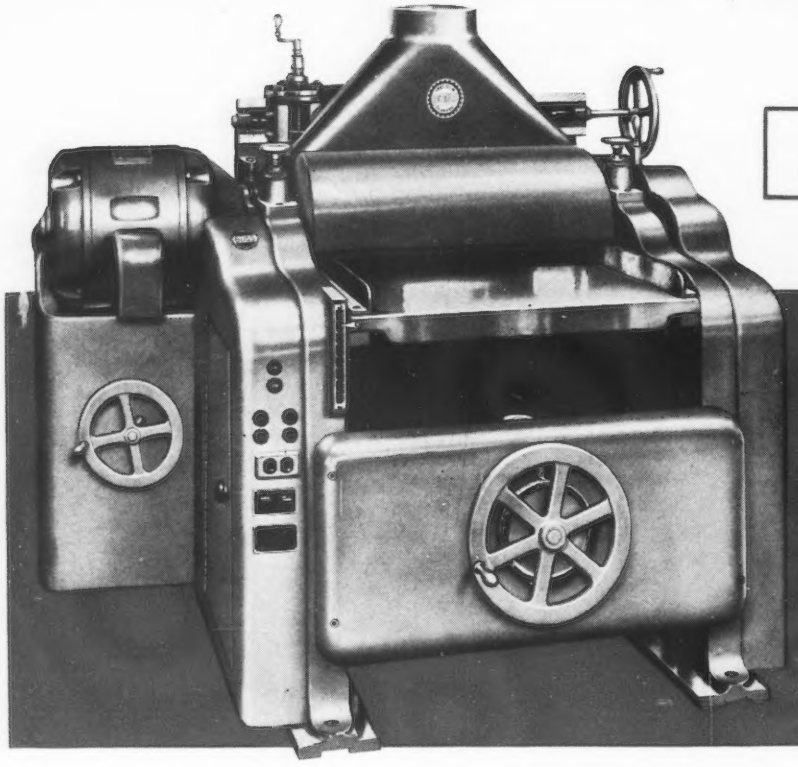

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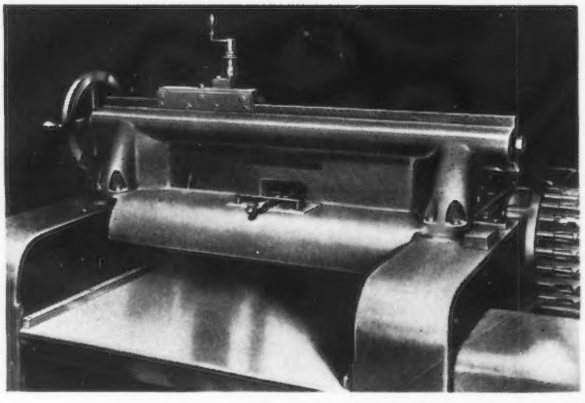

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